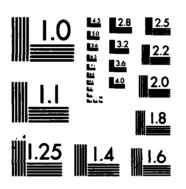
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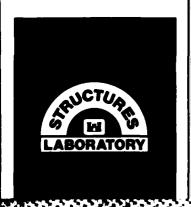


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HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES

by

Kenneth L. Saucier

U. S. Army Engineer Waterways Experiment Station P. O. Box 631, Vicksburg, Miss. 39180



March 1984 Final Report

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Prepared for U. S. Army Corps of Engineers
Missile Construction Office
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20. ABSTRACT (Continued)
Results indicated that it is feasible to achieve the 15,000-psi compressive strengths but that workability may decrease over a 2-hour period, and this latter development should be studied under job conditions. It is recommended that (a) all materials and procedures to be used on a specific project be tested in the laboratory for basic property information, and (b) selected mixtures be tested in the field under expected environmental conditions prior to actual job use.
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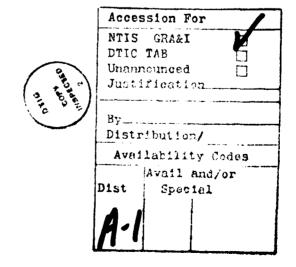
Preface

The investigation described in this report was conducted for the U. S. Army Corps of Engineers Missile Construction Office, Norton AFB, California, by the Concrete Technology Division (CTD) of the Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES). Authorization for the investigation was given in DA Form 2544, No. E87 83-7165, dated 21 March 1983.

The investigation was performed under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John M. Scanlon, Chief, CTD, and under the direct supervision of Mr. Kenneth L. Saucier, Principal Investigator. Mr. Donald M. Walley, CTD, proportioned the concrete mixtures. This report was prepared by Mr. Saucier.

Funds for publication of this report were provided from those made available for operation of the Concrete Technology Information Analysis Center (CTIAC). This is CTIAC Report No. 70.

Commander and Director of WES during the investigation and the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.



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Conversion Factors, Non-SI to SI (Metric) Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	Ву	To Obtain
inches	0.0254	metres
pounds (force) per square inch	6894.757	pascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic yard	0.5932764	kilograms per cubic metre

HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES

Background, Purpose, and Scope

Background

1. Previous work has indicated that concrete with a compressive strength of 10,000 psi* is achievable with present-day technology and materials. Quality materials, use of a low water-cement ratio (W/C), and admixtures are required. More recently the use of more effective admixtures, known as high-range water-reducing admixtures (HRWRA), and a very fine silicon-dioxide powder, known as silica fume, have shown promise for increasing the compressive strength of portland-cement concrete above 10,000 psi.

Purpose

2. The purposes of this program were (a) to conduct a study of the processes and techniques required to produce portland-cement concrete with a compressive strength of 15,000 psi or greater using conventional concreting methods and equipment, and (b) to develop physical property data on the mixtures. Special materials and admixtures were permitted, but the aggregates and cements were selected from those available in the Cheyenne, Wyoming, area. Scope

3. The study consisted of the necessary investigation of materials and methods to produce 15,000-psi concrete. The slump was allowed to vary between 2 and 8 in. Tests included compressive strength at different ages, tensile strength, elastic properties, resistance to freezing and thawing, shrinkage,

creep, and loss of slump with time.

Materials, Mixtures, and Tests

Materials

4. One granite coarse aggregate, designated OM 19 G-1, one limestone aggregate, designated OM 19 G-2, and one limestone sand, designated OM 19 S-1, were received for use in the study. Both project coarse aggregates were washed prior to use. The granite was also screened over a 1-in. sieve to remove

^{*} A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

oversize material. In addition, a laboratory rock was used in a number of mixtures when it became apparent that the large number of trial batches required would exhaust the supply of project aggregate before all the physical property tests could be conducted. A local chert aggregate and a local lightweight aggregate were used in several trial mixtures. Aggregate property data on the project aggregates and the laboratory limestone aggregate are given in Tables 1-4.

- 5. The portland cement was a Type II from Wyoming. Information on the cement is given in Table 5. Results of tests of a Class F fly ash, a Class C fly ash, and the silica fume used in the study are given in Tables 6A, 6B, and 7, respectively.
- 6. A naphthalene-based HRWRA and a melamine-based HRWRA were used in the study. An air-entraining admixture was used in selected admixtures. Fibers were incorporated in three mixtures on a trial basis.

Mixtures

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7. Seventy-six mixtures were proportioned. Results are given in Table 8. In addition to the mixtures given, many batches were discarded when they were found to be harsh or unworkable. The first five mixtures were based on previous experience applied to project material and using the recommended dosage of admixture. Subsequent mixtures introduced the materials and proportions required to provide a comprehensive study of all reasonable combinations. Pertinent information on the mixtures is given in the remarks column of Table 8. Mixing was done according to ASTM C 192-81.

Tests

- 8. Tests were conducted according to the following ASTM standards:
 - a. Slump C 143-78.
 - b. Compressive strength C 39-81.
 - c. Splitting tensile strength C 496-79.
 - d. Modulus of elasticity and Poisson's ratio C 469-81.
 - e. Resistance to freezing and thawing C 666-80.
 - f. Length change on drying C 157-80.
 - g. Creep C 512-82.
- 9. The compressive strength specimens were 3-in.-diameter by 6-in.-long cylinders cured in water until time of test. Due to the very high test strength, compressive specimens were ground to tolerance on a surface grinder rather than being capped. Electrical resistance strain gages were used to record stress-strain data for calculation of modulus of elasticity and Poisson's ratio.

Results

Proportioning

- 10. The proportioning work, Table 8, indicated that it is indeed possible to achieve workable, low W/C concrete with various combinations of the selected materials. Slumps in the range up to 8 in. were secured with water-cementitious ratios approximating 0.25 and without segregation or harshness in most instances. During the proportioning study, however, it became apparent that a slight reduction in W/C or slight increase in admixture dosage could instantly change the workability of a mixture. A decrease of 0.01 in W/C could make a mixture very sticky or an increase of 0.1 percent in admixture dosage could result in a harsh mixture. Apparently, these changes are the result of working near the critical minimum amount of water (W/C = 0.25) and the critical maximum dosage of admixture (1.0 percent of cement). The slump test is not a good indicator of workability under these circumstances. A high-slump mixture may consolidate satisfactorily yet be sticky and hard to move. A high-slump mixture may even "flow" during the slump test, but be very harsh. It is not possible to relate the characteristics of the mixture developed herein directly to a field situation due to variations of materials, the chemistry of the cement and admixtures, and the differences in mixing actions and temperature. These mixtures could, however, be used as a basis for field mixtures to be tried under actual job conditions with job equipment.
- 11. Slump loss tests were conducted on three mixtures, Nos. 38, 48, and 58, to determine loss of workability with time. An initial slump test was conducted immediately after mixing. The concrete was then allowed to be at rest for 25 min, at which time it was remixed for 5 min. This cycle was repeated until the end of the test. Results are given in Table 9. Indications are that some workability will be lost over a period of 2 hr, but the concrete will remain placeable for 2 hr. Redosing with admixture is a viable option for restoring workability, but redosing tests were not conducted in this study. Again, the importance of these tests is to indicate that extended workability is possible to achieve with these mixtures; field tests should be conducted under actual project conditions.

Compressive strength

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- 12. Compressive strength results are given in Table 10. The tests were conducted on 3- by 6-in. cylinders (3 \times 6) unless otherwise noted. Indications are that:
 - a. Compressive strengths of approximately 10,000 psi may be attained at 7-days age with the materials used and the slump specified.
 - $\underline{\mathbf{b}}$. Compressive strengths of 12,000 psi may be achieved at 28-days age.
 - \underline{c} . Compressive strengths of 15,000 psi may be attained at 90-days age.
 - d. Compressive strengths of 20,000 psi may be attained with selected mixtures at extended ages.
 - e. The use of high-range water-reducing admixtures is necessary to achieve the desired strengths at the required slumps.
 - <u>f</u>. Fly ash and silica fume enhance the potential for increased compressive strength.
 - g. High-strength, air-entrained concrete containing silica fume is feasible.
 - h. Fibers may be used in high-strength concrete; however, a significant loss in workability results.
 - i. Lightweight high-strength (10,000-psi) concrete could not be attained with the materials and techniques used herein.
- 13. To facilitate comparison of the two project aggregates, strength results are given in Tables 11 and 12 for limestone and granite coarse aggregates, respectively. A cursory examination of the results reveals that the granite aggregate produced slightly higher strengths for comparable mixtures. However, it is obvious that 15,000-psi concrete may be attained with either of the coarse aggregates and selected cementitious materials and admixtures used in the program.

Splitting tensile strength

14. Splitting tensile strength results are given in Table 13. Tensile strengths of approximately 1200 psi were achieved on several mixtures. Thus, the tensile strength is approximately 9 percent of the comparable compressive strength. This compares to the normally accepted value of 10 percent used for conventional concrete.

Elastic properties

15. Stress-strain curves for 18 specimens tested in compression to failure are given in Figures 1-18. The curves for vertical strain are essentially linear to failure. Some nonlinearity is apparent in the horizontal or

circumferential strain. Young's modulus of elasticity and Poisson's ratio results are given in Table 13. Young's modulus for the representative samples tested approximated 6.0×10^6 psi. This is twice the normally accepted value for conventional concrete. Poisson's ratio varied somewhat depending on the curvature of the horizontal strain curve and at what stress level the ratio was computed. Actual values ranged between 0.20 and 0.25.

Drying shrinkage tests

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16. Results of length change tests, conducted on mixtures No. 22 and 35, are given in Tables 14-17. All specimens were cured in water in accordance with ASTM C 157. For the control tests, Tables 14 and 16, cement was substituted for silica fume on a weight basis. Thus, the total amount of water and the W/C remained constant for all four mixtures. On the 1-in. unrestrained bars expansion was noted in all mixtures. However, significantly more expansion was noted on the mixtures without silica fume. Approximately 0.004 percent shrinkage was noted with the 3-in. bars on the mixtures containing silica fume at 100-days age.

Resistance to freezing and thawing

17. Tests for resistance to freezing and thawing were conducted on three mixtures; one air-entrained limestone coarse aggregate mixture, one air-entrained granite aggregate mixture, and one nonair-entrained granite mixture. Results are given in Tables 18, 19, and 20. After 300 cycles of freezing and thawing all mixtures had a relative modulus (E) of at least 80 percent. At approximately 350 cycles both granite mixtures (air- and nonair-entrained) had a modulus of about 85 percent but the air-entrained limestone mixture had dropped to approximately 70 percent. At approximately 400 cycles the granite mixtures still had a modulus of approximately 80 percent, but the limestone mixture had dropped to 50 percent. All testing was terminated when the modulus decreased to 50 percent on each of the three mixtures. Apparently, the combination of a very dense rock (granite) and a very low W/C provided excellent resistance to freezing and thawing. It would appear that the nonair-entrained concrete did not achieve critical saturation with water under the test conditions used.

Creep tests

18. Creep tests were conducted on specimens from mixture No. 22 with and without silica fume in accordance with ASTM C 512-82. The creep load was 2000 psi. Results for total strain, creep strain, and specific creep up to 3-months age are given in Figures 19-24. At 90-days age indications are that (a) creep is essentially equal for mixtures with and without silica fume, (b) total strain approximated 500 millionths, (c) creep strain approximated 200 millionths, and (d) specific creep was approximately 0.1 millionth per psi.

Conclusions

- 19. The results of this investigation indicate the following:
 - a. It is feasible to achieve 15,000-psi compressive strength concrete with selected cementitious materials and aggregates from the Wyoming area.
 - <u>b</u>. Some workability may be lost over a time period of 2 hr; thus, this phenomenon should be investigated under job conditions.
 - c. Tensile strengths approximating 1200 psi were achieved. Modulus of elasticity was approximately 6.0×10^6 psi and Poisson's ratio was approximately 0.20.
 - d. Shrinkage of typical high-strength concrete containing silica fume was indicated to be on the order of 0.004 percent at 100 days in water.
 - e. Freeze-thaw-resistant concrete was achieved with both project aggregates in an air-entrained mixture. In addition, a nonair-entrained mixture with the granite aggregate developed significant freeze-thaw resistance.
 - f. Creep was essentially equal for mixtures with and without silica fume, approximating 200 millionths of strain at 3-months age under 2000 psi of stress.

Recommendations

20. It is recommended that (a) all materials and procedures to be used on a specific project be tested in the laboratory for basic property information, and (b) selected mixtures be tested in the field under expected environmental conditions prior to actual job use.

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1 } IN.				 			RASION LOS				RADING	1		1	\top		1
1 IN.							, LB/CU FT								T		
3 IN.							E PARTICLE)					T		
1 IN.						SPEC HE	EAT, BTU'L	8.10EG F. (0	RO-	2 1241					\prod		
3 IN.						REACTI	VITY WITH N	• вон		SC,RM/	L:				\perp		
NO. 4					100	ιc	RD-C 128):			RC,MM.	/L:						
NO. B				<u> </u>	83									<u> </u>			L
NO. 16				L.,	63	MORTAR	R-MAKING PR	OPERTIES	CRD	-C 116)						
NO. 30				<u> </u>	42	TYPE	CEMEN	T, RATIO:_		DAYS		<u>, , , , , , , , , , , , , , , , , , , </u>		DAYS			
NO. 50		L		└	16	LINEAR	THERMAL E	XPANSION,	MILL	IONTH	S DEG F	. ICRD-	C 125, 12	61:			
NO. 100		<u> </u>		├	5	ļ	ROCK	TYPE		PAR	ALLEL	ACR	oss	ON		AVER	AGE
NO. 200		ļ		├	-	├				┼		<u> </u>					
-200 ^(q)		<u> </u>		 -	2 0	. 				}							
F.M.(b)		L	L	<u> </u>	2.92	f L				٠		L	1.				
(d) CRD-C	105	(b) CR	D-C 104			MORT	AR:					т-					
MORTAR-	BAR EXF	ANSION	AT 100	F. 7. (CF	RD-C 123):	 	FINE AGO				+	~ 7-	ARSE AG			
}							2 MO.	6 MO.	-9-	мо.	12 MO.	1 3	MO	6 MO.		MO.	12 MO.
	LK. CEM					VALENT:	+	 	-			+					
SOUNDNE			E (CRO-											FAT	,,,,,	-CD	HD-CW
FINE A		HCHE.	e icho	40, 110		RSE AGG						DFE			-~-	-	
FINE A						RSE AGG						OFE					
PETROGR		ATA IC	RD-C 12	71.													
}																	
ļ																	
1																	
ĺ																	
ľ																	
ĺ																	
{																	
REMARKS																	
}																	

STATE.	la.	INDE	x no	6 (5	Suppl	l 7)	AGG	REGATE		TESTE	D BY:	USA	EWES			
LAT 3	33 N	LON	s 8 6	5 W				A SHEET		DATE.	3	Fe	ь 19	75		
LAB SYM	BOL NO.	CL	−2 G-	-1, 1	1s-l				TYPE	OF MAT	ERIAL	Li	mest	one		
LOCATIO	N Se	<u>c. 8</u>	, T 2	22 S	_ R	2 W, 1	1/2 m	iles N	W	of Ca	lera	ı, A	la.	(Cale	ra Quar	ry)
																
PRODUCI	ER Vu	lcan	Mate	eria.	Ls Co	o., Bi	rmingh	am, Al	<u>a.</u>							
SAMPLEC		IICA	EWES	-						-						
TESTED			orato	rv S	Stock											
USED AT			EWES													
PROCESS	ING BEF	ORE TE	STING.													
GEOLOGI	CAL FOR	MATIO	N AND A	GE												
						T	T				1			-т	_ _	r
GRAD	ING ICRE	-C 103)	(CUM. 5	PASSIN	iG):	ļ	TEST	RESULTS			3	-6"	1 1 -3	2-13	44-2"	FINE AGG.
SIEVE	3-6"	1 2-3	2-13	24-1	FINE AGG.	Bu × 66	GR, \$.5.D.	(CBD-C 10)	106		+				2.69	
6 IN.	\vdash			 			TION, TICR				+			-	0.5	
5 IN.							IMPURITIE			D-C 121)	1-			-1	-† <u></u>	
4 IN.							RTICLES, "									
3 IN.						* LIGHT	ER THAN SE	GR	ICRI	D-C 122)	\perp					
2 1 IN.					ļ	1 FLAT	AND ELONG	ATED (CRE	-C 11	9, 120)					\downarrow —	
2 IN.	<u> </u>						LOSS, 5 CY				Л					ļ
1; IN.	ļ				 		RASION LOSS			145) GR	ADING_			-	-	
1 IN.	-		100	 			, LB CU FT				+			-		
3 IN. 1 IN.			96	-	-	-	PARTICLE				+			-	 	
3 IN.			47 19			SPEC HEAT, BTU/LB/DEG F. (CRD-C 124) REACTIVITY WITH NGOH SC.MM/L:										
NO. 4	<u> </u>	-	0			t	RD-C 1281:		г	RC,RM.'L	\neg				1	1
NO. 8																
NO. 16						MORTAR	-MAKING PR	OPERTIES	(CRD	-C 1161						
NO. 30			L	ļ	ļ	TYPE_	CEMEN	T, RATIO:_		DAYS,		٦.		DAYS		`
NO. 50			<u> </u>	<u> </u>	ļ	LINEAR	THERMAL E	XPANSION,	MILL	IONTHS/	DEG F	(CRD-	C 125, 1	261:	1	
NO. 100	_				 	 	ROCK	TYPE		PARAL	LEL	ACR	1055	ON	AVER	AGE
NO. 200			ļ	\vdash	1	├			_	 						
F.M. (b)					İ	 				†				<u> </u>		
(e) CRD-C	105	(b) CR	D-C 104		1	MORTA	NR:							•		
MORTAR-				E 7 /C1	PD-C 12			FINE AGO	REG	ATE		<u> </u>	c	OARSE AG	GREGATE	
	DAN EAR			, » (C)	10-C 12.	•···	2 MO.	6 MO.	9	MO.	12 MQ.		мо.	6 MO.	9 MO.	12 MO.
	LK. CEM					VALENT:	ļ					—				
	ALK. CEN					VALENT:	J	L			-	Т				
SOUNDNE FINE A		NURET	E ICRO-C	40, 114		RSE AGG:						DFE 3		FAT	HW-CD	HD-CW
FINE						RSE AGG:						DFE 3	$\neg \neg$	-		
PETROGE		ATA (C	RD-C 12	71:												
i																
:																
REMARKS														· · · · · · · · · · · · · · · · · · ·		

TO: Structures Laboratory Waterways Exp Station ATTN: Ken Saucier		REPORT OF	TESTS OF .	Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit					
P. O. Box 631			••		0. Box 6		IIIL		
Vicksburg, MS 39180	1	RC 894			ksburg,		80		
			EPRESENTED:	1 410	 _				
TEST PEPCRT NO. WES-171-83					21 April		83		
SPECIFICATION: ASTM C 150.				SAMPLED	21 April	1903			
	ECIFICATION R	ON Lara	III e. WI		I BRAND:				
	1			7					
SAMPLE NO	20.6					 			
A ₁₂ 0 ₃ .	4.3					 			
	3.2			 -		 	 		
Fe ₃ 0 ₃ . ** M₃0, **	0.9		+			+	 		
so,.			i -	 -		 			
	2.3						+		
LOSS ON IGNITION T	0.35						 		
No. 70. %	0.12					 	- 		
	0.35			- 			+		
K ₂ D. T	0.52					+	+		
Cao. *	64.5								
	65								
C ₃ S. *	6			-i -					
	10	—— i —		_ _		 -	┽		
C.5	71								
2,4 + 0,5 *	10					 -			
C ₄ AF	22								
C, AF + 2 C, A	22					+			
HEAT OF HYDRATION, 7D. CAL G					 				
HEAT OF HIDPATION, 28D. CAL G	4030			- ; -	 -				
SURFACE AREA, SQ CM G (A P.) A:R CONTENT.	8								
	3600								
COMP. STRENGTH, 3 D, PSI	4770					 	 		
COMP STRENGTH, 7 D, PSI									
30 m : 31 NENGTICE	6090					 			
FALSE SET - PEN. F 1, 7						 -			
SAMPLE 10.	1								
AUTOCLAVE EXP.,	0.02						 		
INITIAL SET, HR'MIN	2:45					 			
FINAL SET, HR/MIN	4:25		 						
SAMPLE NO.									
AUTOCLAVE EXP., -						 			
INITIAL SET, HR'MIN						 			
FINAL SET, HR/MIN									
INITIAL SET, HR'MIN	Concrete	Program	- Ken Sau	cier					
THE INFORMATION GIVEN IN THIS REPO OR IMPLICITLY ENDOMSEMENT OF THIS	RT SHALL NOT PRODUCT BY T	X 1	E. REINA	Jich	TION TO INDICA	TE ÊITHER E	XPLICITLY		

ENG FORM 6308-R

1.4000									_			
CVACH V	TORY:									REPORT	NO.:	
Struct	tures Lai	bo <u>r</u> at	ory	1	9.	PORT	ΩF	TESTS		WES-	319F-79	
USAE W	Vaterway:	з Ехр	St	[ON POZ		•				-
	•	OZZ 1	.est 1	31				960/5		SHEET	1 °F	1
	30x 631	391	80			AD-	590	n		DATE:	16 July 7	19
/ickst	ourg, MS	371	.60					-			6 August	. 79
CLASS ((F) N	KI	ND OF P	OZ ZOLAN:	F	ly A	sh					
SOURCE:	William:	s Bro	s.,	Atlant	a, G	A				BRAND:		
TEST RE	SULTS OF THE	S SAMPL	.E LOT)	COMPL	-Y 🗆	DO NO	T C	OMPLY WITH	SPEC	IFICATION L	IMITS (SEE REM	LRKS
FOR USE	AT:											
CONTRA	CT NO.:											
DISTRICT	r(\$):											
SAMPLE	Str	ictur	es Br	anch					DATE	SAMPLED: 2	July 79	
CAR NO.:				BIN NO.	:							
FIELD SA	MPLE NO.:						$oldsymbol{ol}}}}}}}}}}}}}}}}$	LAB SAMPL	E NO.:			
DATE RE	CEIVED:	2 Jul	у 79				\perp	LAB JOB N	0.:			
	ev: Cem &							CHECKED	BY:			
TESTS O	N COMPOSITE	OF THE	100-TON	SAMPLES	LISTED	SELOM						
SiO ₂ + Al	20,	_			AVAIL	ABLE	P	OZZOLAN	INC	REASE IN	AUTOCLAVE	REDUCTION IN
+ Fe	, O,	0	so	2	ALKA		5	TRENGTH		RINKAGE	EXPANSION	EXPANSION
3.						· j	-	CONTROL		~ (a)	· ·	% (6)
						REQUIR	EME	ENTS				
MIN 70.	O MAX	5.0	MAX	4.0	WAX	1.5		MIN 75	<u> </u>	E0.0 XA	MAX 0.50	MIN 75
						TEST R						
88.5	1	. 3	0.	. 7	* 0.	65	*	91	<u> </u>		0.03	
								TING 100 T	ONS OF	LESS		
				inene						WATER		SP GR
SAMPLE	MOISTURE	LOSS	ON 3	125 Mes	sh va	ar fi	rot	n LIME N POZZOLA	N RE	QUIREMENT	SPECIFIC	VARIATION FROM
NO.	CONTENT	IGNIT	, S	ieve 2	(a	vg pi	re	STRENGT	H	% of	GRAVITY	AVERAGE OF PRECEDING
	l		P	letaine	èd∤	10		2"cube	s Co	ntrol		10, %
						REQUIR	EME	NTS				
	MAX	10.0		MAX		MAX	\Box	MIN		MAX		MAX
	3.0	6.0		34_		5		900		105		5
						TEST R	ESU	. 78				
_1						1201 1						
	0.5	<u> </u>	0	21			\Box	1120		97	2.43	
	0.5	2.	0	21	-]		D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21					D	97	2.43	
	0.5	2.	0	21						97	2.43	
AVERAGE	0.5	2.	0	21				1120				
	CABLE ONLY T	O CLASS		21				1120				AL, WES-21
(a) APPLI	CABLE ONLY TH	D CLASS	N			BORATO	- OPRY (112(o Al	pha,Bir	mingham,	
(a) APPLI	CABLE ONLY TH	D CLASS	N			ECRATO Tequ	- Park (1120	Al	pha,Bir mstone *28 day		AL, WES-21
(a) APPLI	CABLE ONLY TH	D CLASS	N			ECRATO Tequ	- Park (1120	Al	pha,Bir mstone *28 day	mingham,	
(6) APPLIO	CABLE ONLY TH	CLASS	N			ECRATO Tequ	- Park (1120	Al	pha,Bir mstone *28 day	mingham,	
(6) APPLIC (b) OPTION	CASLE ONLY TO NAL REQUIREM MEETS	CLASS	N			ECRATO FEQUENCY W.	DRY G	112(Al	pha,Bir mstone *28 day	mingham,	
(6) APPLIC (b) OPTION	CASLE ONLY TO NAL REQUIREM MEETS	CLASS	N			W. Che	DAY G	TILLI	AI Che	pha.Bir mstone *28 day	mingham,	oort

ENS FORM NO. 6000-F

Struct	omy ures La	borato	ry					REPORT WE:	но. S-42C-83	
	vays Exp				REPORT OF			<u> </u>		
	Cem & P				ON POZZ	OLAN		SHEET	l of	1
	Box 631							DATE	23 Februa	1093
Vicks	ourg, MS	3918	30		AD 7	12		L	23 March	
CLASS	F (C 1 N	KIND	OF POZZ	OLAN						
SOURCE:		Ash,						BRAND:		
TEST RES	ULTS OF THIS	SAMPLE L	от 🔀	COMPLY	DO NOT	COMPLY WIT	H SPEC	FICATION	LIMITS ISEE REM	ARKS)
FOR USE		ld Riv	ver A	uxili	ary Stru	cture				
DISTRICT		·					-			
SAMPLED				-			DATES	AMPLED:	8 Feb 83	
CAR NO.			- 1	BIN NO.:					O TED 03	· · · · · · · · · · · · · · · · · · ·
	MPLE NO.:					LAB SAME	LE NO.:			
DATE RE		1 Feb	83			LAB JOB	NO.:			
TESTED		em & P		init		CHECKED	BY:			
	COMPOSITE				STED BELOW					• • • • • • • • • • • • • • • • • • • •
SIO, + Al.				- ;	$\overline{}$		T			
+ Fe	Mg		so,		VAILABLE ALKALIES	POZZOLAN		REASE IN RINKAGE	EXPANSION	- REDUCTION IN
•	203	٠ ا	*,			CONTROL		· (a)		7. (6)
		<u>-</u>			REQUIRE	MENTS			·	· · · ·
WIN 70.	D MAX	5.0 ;	MAX5.	0	MAX1.50	MIN 75	м	AX 0.03	MAX 0.8	MIN 75
				<u> </u>	TEST RE	SULTS			 	
59.0	5	.5	3.2		1:	* 105			-0.01	-
			TEST	S ON SAM	PLES REPRES		TONS OR	LESS	·	
1			Fir	neness	s % pts	Ī	1			SP GR
SAMPLE	MOISTURE	ì . LOSS OF	√່32:	5 Mesl	h var fr	OM POZZOL	AN RE	WATER QUIREMENT	SPECIFIC	VARIATION FROM
NO.	CONTENT	IGNITIO	[™] Si∈	eve %	avg pr	ev STRENG	TH :	% of	GRAVITY	AVERAGE OF
		:	Ret	taine	d 10		Co	ntrol		10.
					REQUIRE	MENTS		•		
	MAX	MAX		MAX	MAX	MIN		MAX		MAX
	3.0	10.0 (N) 6.0 (F)		34	5	; 900	<u> </u>	105	1	. 5
					TEST RE	SULTS				
1	0.1	0.2	1	12	2	1830		98	2.75	2
										<u> </u>
						<u> </u>				<u>:</u>
Ca0 %	: 25.0								·	<u> </u>
										-
			i		· · · · · · · · · · · · · · · · · · ·		<u> </u>			* · · · · · · · · · · · · · · · · · · ·
						<u> </u>			·	
		:				i			!	
						i				
AVERAGE						<u> </u>	<u> </u>		: -	
	CABLE ONLY T					Y CEMENT U		rkansa: mstone	s, Foreman	n, ARK
	NAL REQUIREM	ENT			LABORATOR	Y LIME USED	70116			
REMARKS:	Meet	s 7 da	y spe	ecific	ation	quirem	ents,	, *28 ,0	day test i	results
			•		K		ノド		-	
				_	10	Seu	stil	M		
						REINHO		,		
L						<u> </u>			an Unit	
					L NOT BE USED				TION TO INDICATE	EITHER
		LICITLY	ENDORSE	MENT OF T	17415 PRODUCT B	,, ima, u. a. (~~ A = WAN	erd I .		

ENG FORM NO. 6000-R

System temperature secret heavyon alexages anapasy

Table 7 CORRECTED 12 APRIL 1983

LABORATORY		}			REPORT	NO.:	
Structures La	boratory		000000		WES	5-43S-83	
Waterways Exp	Station		REPORT O				
ATTN: Cem & P	ozz Unit	1	UN FUL	FAPVIA	SHEET	1 05	2
P. O. Box 631		1	AD 5	36(5)	DATE: 2	23 Februar	
Vicksburg, MS	39180	ļ				8 March 1	
CLASS # N	SIND OF POZ	ZOL 4N	Silica	Fume		- institt 1	. , , , , ,
	 				BRAND:		
TEST RESULTS OF THIS	ds Metals.					IMITE ISSE BENE	nuel .
				COMPETATION	SPECIFICATION C	THIT I THE REWA	
Fineness (AP)	m ² /kg: 25	04, e=	7.727				
71 11	. 38	06, e=	0.700				
	-2 /: 4/	83, e=0	J.6/8				
Extrapolated	m ² /kg:127	<u>80. e≃(</u>).500 <u>.</u>	Correlati	on Coeffi	cent: -1	
Date Sampled:	10 Feb 83						
FIELD SAMPLE NO.:	11 5			LAB SAMPLE			
	11 Feb 83			LAB JOB NO.			
	m & Pozz U			CHECKED BY	<u> </u>		
TESTS ON COMPOSITE O	F THE 100-TON SA	MPLES LIST	ED BELOW				
5102 + Al203		i ava	HLABLE ,	POZZOLAN	INCREASE IN	AUTOCLAVE	REDUCTION IN
+ F+ O ₃ Mg(KALIES	STRENGTH	SHRINKAGE	EXPANSION	EXPANSION
		ì	•	- CONTROL	~ (a)	. *	~ (b)
			REQUIRE	EMENTS			·
MIN 70.0 MAX	5.0 MAX5	0 4	×1.50	MIN 75	E0.0 XAM	MAX 0.8	MIN 75
			TEST RE	ESULTS	·		
·				* 109		-0.14	
·	TEST	S ON SAMPI	ES REPORS	ENTING 100 TO	S OR LESS		<u> </u>
			% pts				
MOISTURE					WATER	•	SP GR VARIATION
SAMPLE : SONTENT	IGNITION : C4	eve %	. vai ii	ev STRENGTH	REQUIREMENT	SPECIFIC	FROM AVERAGE OF
				PSI		•	PRECEDING
	ĸe	tained	10	<u> </u>	Control		10, 5
			REQUIRE	EMENTS			,
MAX	10.0 (N)	MAX	MAX	MIN 900	MAX		MAX
	6.0 (F)	<u>34</u>	5	900	105	·	-
			TEST RI				
_1	· · · · · · · · · · · · · · · · · · ·	1	_	. 2140	* 120	2.25	<u> </u>
Heat of Hydra	tion						1
Portland Ce	ment, RC 8	83(4)				W/C:0.27	W/C:0.40
				7	days:	56	75 cal/
					days:	62	83 "
RC883(4), 85g	+ AD536(5	150	+ 111				
		-1 45		_	days:	50	53 "
	· · · · · · · · · · · · · · · · · · ·		<u> </u>		days:	48	61 "
			 		uays.	40	; 01
	· · · · · · · · · · · · · · · · · · ·			<u> </u>	†	 	
AVERAGE -			<u> </u>	 	 		·
					United.	Artesia,	MS
(a) APPLICABLE ONLY TO (b) OPTIONAL PEQUIREME				RY CEMENT USED RY LIME USED	Chemstone		
*Fails	water red	uireme	at.	<)	1 .		
			, Q	シノハノ	[
		· /	16	Xinel	alst		
		•	R. E.	REINHOLI	5 7		
					& Pozzola	n Unit	
NOTE. THE INFORMATION	GIVEN IN THIS DED	ORT SHALL A					FITHER
EXPLICITLY OR W	PLICITLY ENDORSE	MENT OF TH	S PRODUCT	BY THE U. S. GOV	ERNMENT.		

ME FORM NO. 6000-R

TABLE 8 HIGH-STRENGTH MIXTURES

Remarks	Slump too low; used D-19 HRWR admixture. Upped the W/C for more slump.	the the	Concerned about high W/C and strength. Lowered S/A. Used WES rock.	Repeat of last mix using WES rock and 0.5 HRWR.	Repeat of last mix lowering W/C, upping HRWR using WES rock.	Repeat of last mix lowering W/C even more and upping HBWR to 0.8.	Repeat of No. 8 increasing HRWR to 0.8 and S/A to 40% or workability.	Modification of No. 7 decreasing the W/C and using 0.8 HRWR. Too stiff.	Repeat of last one using 0.28 W/C at the beginning. Acceptable.	Upped W/C; still concerned that W/C of 0.30 too high.	Upped HRWR, upped S/A, lowered W/C; error increased CMT and decreased fume.	Lowered HRWR and slump just fell inside criteria.	Brought HRWR down some more, slump came down with it. 0.K.	Just to see what No. 15 would look like using right CMT & fume.O.K.	Upped the W/C to See if 1.0 HRWR would compare to 1.25 at 0.24 W/C. It did.	First fume-fly ash mixture (15% each by weight). Looked good.	Slightly harsh; vibrated 0.K.	Better looking than 21; less harsh; vibrated well.	Lowered W/C; same as 22; looked good.	Sticky; vibrated, but hard to work with.	Very sticky; balled up; added 0.2% HRWR to make placeable.	Not sticky, but harsh; appearance of being wet.
S/A	38 88	8 9	38	38	38	38	07	38	38	38	07	70	40	40	07	40	70	40	04	40	40	40
Slump in.	1/2 2-3/4	5-1/2 6-1/2	1 50 6	1-1/4	1-1/2 to 6-1/2	1-1/2	6-3/4	T.	2	9	9-1/2	∞	2-1/5	3-1/4	3 to 9		ო	7-3/4	3-1/2	∞	3	3-1/2
% HRWR per 100 # cmt mtls	5.00	0.00	0.5		0.7-0.8	8.0	8.0	0.8	8.0	8.0	1.86	1.16	0.93	1.25	1.0-1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0
W/C By wt	0.27	0.32	0.28	0.30	0.28	0.26	0.30	0.28	0.28	0.30	0.24	0.24	0.24	0.24	0.26	0.24	0.24	0.24	0.22	0.24	0.22	0.24
Cement/ Sil. Fume/ Fly Ash/ lb/cu yd	940	940 940	940	799/141	799/141	799/141	799/141	799/141	799/141	799/141	859/139	859/139	859/139	799/141	799/141	658/141/ 141	799/141	621/656	959/169	940	076	799/141
Rock	ST ST	ST ST	WES	WES	WES	WES	WES	LS	rs	ΓS	WES	WES	WES	WES	WES	WES	rs	ΓS	rs	ပ	ပ	ပ
Mix- ture No.	1 5 7 3	14 0	9 1	~ ∞	6	10	11	12	13	14	15	16	17	18	19	20	21	22	23	54	25	26

TABLE 8 (CONTINUED)

		Remarks	Looked better than No. 26; vibrated well.	Made to compare to No. 21. Worked good; sand helped.	Very sticky; vibrated well; slump cone flowed; 2 min. extra	mixing.	Very sticky; vibrated well; slump cone flowed; 2 min. extra	mixing.	Not at all sticky; vibrated very well.	Left out the fly ash by error.	Got it right this time. Very good mix; not sticky; vibrated	easily.	#20 with project granite. Handled as good as No. 33.	No. 22 mix with project granite. Almost too wet. Not at all	sticky.	This is mix No. 27 over again using project granite; unscreened,	uncrushed, unwashed.	This is mix No. 33 over again using project rock, unscreened,	unwashed.	First mixture using Rheobuild 561 HRWR; not at all sticky;	Soon vibiating. Air twis misting D.10 UDLD It took / on to entrois	5.3% afr.	First Melment (33%) mixture; not sticky; 7.4% air; finished good.	Melment again; 3.5% entrained air; good mix in all respects.		Mix 16 using 10% silica fume replacement of cement.	Rheobuild 561 HRWR; 1% solids.	Mix 16 with 20% silica fume replacement of cement.	4.5% air entrained.	Accidentally doubled HRWR; got 10-in. slump for 3 hr.	Maintained $3-1/4-in$. slump for 2 hr.	Mix No. 16 with 200 cu yd steel fibers $(0.010 \times 0.022 \times 1.00 \text{ in.})$.	Substitute Class C fly ash for silica fume on weight basis.	
	S/A	»	40	45	40		40		40	07	40		40	40		40		40		40	٧,	}	40	40	40	40	40	40	40	40	40	40	40	
	Slump	ţn.	7	٣	n		2-1/5	•	2-3/4	7	3-1/2		3-1/2	∞		4		6-1/2		6	7/6-3		œ	4	1-3/4			2	8-3/4			1/4	œ	
	% HRWR per 100 #	cmt mtls	1.0	1.0	1.0		1.0		1.0	1.0	1.0		1.0	1.0		1.0		1.0		30 oz.	a C	•	40 oz.	40 oz.	25.5 oz.	1.16	1.00	1.16	8 oz.	2.00	1.00	1.16	1.00	
	W/C By wt	mt mtls	0.26	0.24	0.24		0.24		0.20	0.24	0.24		0.24	0.24		0.26		0.24		0.30	90	07.0	0.30	0.26	0.24	0.24	0.24	0.24	0.30	0.24	0.24	0.24	0.24	
Cement/	Sil. Fume/ Fly Ash/	1b/cu yd c	799/141	799/141	799/0/141		799/0/141	•	902/226	658/141/0	658/141/	141	658/141/141	929/169		799/141		658/141/141		799/141	1717007										859/139			
		Type					rs							ဗ		ပ		rs		WES	1700	S S	WES	WES	WES	WES	WES	WES	WES	WES	WES	WES	WES	
	tx- ure	No.	27	28	29		30		31	32	33		34	35		36		37		8 8	90	,	40	41	42	43	77	45	94	47	48	49	20	

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TABLE 8 (CONCLUDED)			Kemarks	20% by weight cementitious materials substituted with Class C flv ash.	30% by weight cementitious materials substituted with Class C fly ash.	Mix with special cement; unsuccessful.	Good mix; vibrated well.		Control for mix 57; used Melgran.	2% calcium chloride used; very stiff; no slump test.		Repeat of mix 16 using 1-in. fiberglass fibers = 14.8#/cu yd.	Repeat of mix 16 using fiberglass fibers = 24.3 /cu yd.	Repeat of mix 16 using polypropylene fibers = 14.8 //cu yd.	Attempt to entrain air; batch discarded.	Not cast.	Air entrained for freeze/thaw beams (4.6%).	Non-air-entrained; control for mix 64.	Air entrained for freeze/thaw beams (4.0%).	Air entrained at 2.5%; added AEA to get 5.8%.	Control for mix 67.		3/8-in. expanded clay lightweight coarse aggregate (119.7#/cu ft).	3/8-in. expanded clay lightweight coarse aggregate (116.9#/cu ft).	Lightweight aggregate. Wet unit weight = 121.2 /cu ft; 4.0% air.	Repeat of mix 22; cast creep and shrinkage specimens.	Repeat of mix 22 without silica fume. Cast shrinkage specimens.		Repeat of mix 35 without silica fume. Cast shrinkage specimens.
IABL		S/A	N4	40	40	40	07	40	40	40	40	40	40	40	40		40	40	40	40	07	40	39.5	45	45	40	40	40	70
		Slump	TH.	9-1/4	8-1/4	01	5-1/2	∞			8-1/2	1/4	1/2	1/2			8-1/2	9-1/4	8-1/2	8-1/2	6	7	2	10-1/2	::	7	7	œ	∞
	% HRWR	per 100 #	CMT MTIS	1.00	1.00	1.16	1.00	1.16	2.00		1.25	1.16	1.16	1.16	1.25		1.25	1.25	1/25	1.24	1.25	1.25	1.25	1.25	1.25	1.0	1.0	1.0	1.0
	M/C	By wt	CHT HTIS	0.24	0.24	0.42	0.29	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24		0.24	0.24	0/24	0.24	0.24	0.24	0.24	0.24	0.22	0.24	0.24	0.24	0.24
Comont	Stl. Fume/		1b/cu yd	752/188	658/282		, -		0/091/08/	780/160/0		859/139/0	859/139/0	859/139/0	799/141		799/141	799/141	799/141	799/141/0	799/141/0	846/94/0	799/141/0	879/155/0	959/169/0	929/1469/0	1143/0/0	959/169/0	1128/0/0
	•,		Type	WES	WES	WES	Chert	WES	Chert	Chert	WES	WES	WES	WES	WES		WES	WES	r.s	ტ	ც	LS	LTW	LTW	LTW	ΓS	ΓS	ც	ა
	M	ture	è	51	52	53	54	55	26	57	28	59	09	61	62	63	99	65	99	29	89	69	20	71	72	73	74	75	9/

LS - Project Limestone WES - Laboratory Limestone G - Project Granite LTW - Lightweight NOTE: Aggregates:

Table 9 Slump Loss Tests

Mixture No. 38

W/C material: 0.30

S/A percent volume: 40

Cement/silica fume content, lb/yd³: 799/141

WES 3/4 limestone aggregate

Rheobuild 561 HRWR at 30 fl oz./cvt materials.

Time, hours	Slump, in
0	9
0.5	7-3/4
1.0	7-3/4
1.5	7-3/4
2.0	7-1/2
2.5	5-1/2

Mixture No. 48

W/C material: 0.24

S/A percent volume: 40

Cement/silica fume content lb/yd each: 859/139

WES 3/4 limestone aggregate

W. R. Grace D-19 HRWR 1.0% by wt. cement materials.

Time, hours	Slump, in.
0	3-1/4
1	6
2	4

Mixture No. 58

W/C material: 0.24

S/A percent volume: 40

Cement/silica fume content, 1b/yd³ each: 799/141

WES 3/4 limestone coarse aggregate

W. R. Grace D-19 HRWR 1-1/4% by wt cement materials.

Time, hours	Slump, in.
0	8-1/2
1	8
2	4

Table 10
Compressive Strength Test Results

		Notes				2												
***	11	90 days	8,820	10,560		10,630	6,170	9,790	12,790	7,030		8,840 (175 days)	11,950 (175 days)	12,590 (175 days)	12,170 (175 days)	8,030 (174 days)	15,420 (167 days)	
	Compressive Strength, psi	28 days		9,830		6,440 (19 days)	6,270	8,190 (18 days)	11,650	7,780 (18 days)					12,410			;
	Compressive	14 days	7,350 (19 days)	7,340 (19 days)	6,780 (19 days)				9,527 (18 days)							096,9		
)	7 days	6,350	5,590	7,670	5,350	4,890	7,780	6,300	2,640	7,670	8,040	8,560		8,830	6,470	10,840	
	Slump,	in.	1/2	2-3/4	2	5-1/2	6-1/2	-	9	1-1/4	6-1/2	1-1/2	6-3/4	1	2	9	9-1/2	
Cement/Silica	Fume/Fly Ash,	1b/yd ³ each	0/0/076	0/0/076	0/0/076	0/0/076	0/0/076	0/0/076	799/141/0	799/141/0	799/141/0	799/141/0	799/141/0	799/141/0	799/141/0	799/141/0	859/139/0	
	M/C	Ratio	0.27	0.28	0.30	0.32	0.32	0.28	0.30	0.30	0.28	0.26	0.30	0.28	0.28	0.30	0.24	
Mix-	ture	No.	Т	2	e	4	5	9	7	80	6	10	11	12	13	14	15	

(Continued)

Table 10 (Continued)

	Notes														F" fly ash	F" fly ash			ica fume and	ica fume and
psi	0 days	16,900 (167 days)	18,100 (167 days)	19,100 (167 days)	18,670 (165 days)	18,460 (165 days)	15,700	17,080	17,580	14,290	14,470	18,780 (153 days)	17,440 (153 days)	15,630 (152 days)	15,810 Used Class "F" fly	13,580 Used Class "F"	17,330 (148 days)	16,200 (148 days)	16,370 Mix with silica fume and (148 days) "F" fly ash	17,470 Mix with silica fume and (148 days) "F" fly ash
Strength,	28 days	16,830	16,660	17,750	15,910	15,210	14,820	14,640	13,970	12,490	11,920	14,680	14,460	12,800	12,990	11,180	14,290	13,510	14,290	14,000
Compressive Strength, psi	14 days				13,470 (11 days)	13,480 (11 days)														
	7 days	10,470	11,600	11,100	12,940	11,810	11,650	12,110	12,025	10,195	11,795	12,490	10,315	11,255	10,110	09,760	10,930	8,470	9,740	9,650
Slump,	in.	∞	2-1/2	3-1/4	6	3-1/2	er.	4-3/4	3-1/2	œ	e	7	3	6	က	2-1/2	2-3/4	7	3-1/2	3-1/2
Cement/Silica Fume/Fly Ash,	1b/yd3 each	859/139/0	859/139/0	799/141/0	799/141/0	658/141/141	799/141/0	959/169/0	959/169/0	0/0/076	0/0/076	799/141/0	799/141/0	799/141/0	799/0/141	799/0/141	902/226/0	658/141/0	658/141/141	658/141/141
W/C	Ratio	0.24	0.24	0.24	0.26	0.24	0.24	0.24	0.22	0.24	0.22	0.26	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Mix- ture	No.	16	17	18	19	20	21	22	23	77	25	26	27	28	53	30	31	32	33	34

(Correinned)

Table 10 (Continued)

SOME STATEMENT OF THE STATEMENT OF STATEMENT

	Notes		Harsh mix; 4 by 8 cylinders	8 days)	6 days)	5.3 percent air	7.4 percent air	12,000 @ 1/3 days 3,3,2pergeptsajr	13,570 @ 1/3 days 17,540 @ 152 days	18,000 @ 152 days	17,270 @ 151 days	17,330 @ 151 days	4-1/2 percent air	10,510 % 14/ days 2 percent high-range water reducer plus conventional water-reducing admixture		Steel fibers at $200 \mathrm{lb/yd}^3$	101 El. 201
osi	90 days		13,745	16,130 (138 days)	16,300 (116 days)		(119 days)	(13,793ys)	(17,620°s)					16,300 (139 days)	17,820	18,000	000
Compressive Strength, psi	28 days	16,300	13,010	13,390	13,860	12,450	11,560	12,910	16,175	16,500						16,270 (54 days)	12 020
Compressive	14 days																000
	7 days	10,120	10,910	11,050	9,920	009.6	8,550	9,480	11,410	11,730	9,370	10,150	7,450	11,365	12,200	12,695	
Slumb	in.	œ	4	6-1/2	6	6-3/4	∞	7	1-3/4	6	3-1/2	5	8-/34	10	3-1/4	1/4	c
Cement/Silica Fume/Flv Ash	1b/yd each	959/169/0	799/141/0	658/141/141	799/141/0	799/141/0	799/141/0	799/141/0	799/141/0	898/100/0	799/141/0	798/200/0	799/141/0	859/139/0	859/139/0	859/139/0	171707002
J/13	٥١	0.24	0.26	0.24	0.28	0.28	0.30	0.26	0.24	0.24	0.24	0.24	0.30	0.24	0.24	0.24	2
Mix-	No.	35	36	37	38	39	70	41	42	43	77	45	97	47	87	67	Ç

(Continued)

Table 10 (Continued)

í		ļ						s t	st	_				
		Notes	Class "C" fly ash; too wet, segregated	Class "C" fly ash		Chert gravel aggregate		Mix with $CaCl_2$; see $24-hr$ test curve	Mix with $CaCl_2$; see 24-hr test curve	19,380 20,760 psi at 164 days, on a (108 days) 4 by 8 cylinder	Repeat of mix 16 with fiber- glass reinforcement	Repeat of mix 16 with fiber- glass reinforcement	Repeat of mix 16 with poly- propylene fibers	Not cast
	psi	90 days	15,420 (133 days)	16,910 (133 days)	4,530 (133 days)	12,560 (114 days)	18,420 (113 days)	!	1	19,380 (108 days)	16,200 (107 days)	17,050 (107 days)	13,760 (106 days)	
	Compressive Strength, psi	28 days	14,610	14,460	3,490	12,480	16,400	10,050	8,220	17,890 (42 days)				
	Compressive	14 days	10,650 (10 days)	10,700 (10 days)	2,350 (10 days)	9,950 (10 days)	~							
		7 days					11,600 (8 days)	8,550	7,500		10,400	10,900	9,100	
	Slump,	in.	9-1/4	8-1/4	10	5-1/2	œ			8-1/2	1/4	1/2	1/2	
Cement/Silica	Fume/Fly Ash,	1b/yd ³ each	752/0/188	658/0/232	798/200/0	799/141/0	658/141/141	780/160/0	780/160/0	799/141/0	859/139/0	859/139/0	859/139/0	
	M/C	Ratio	0.24	0.24	0.42	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	
Mix-	ture	No.	51	52	53	54	55	99	57	58	59	09	61	62

(Continued)

Table 10 (Concluded)

ngth, psi	0 days		14,260 16,020 Air = 4.6 percent; cast three (35 days) (105 days) freeze-thaw beams	16,440 18,960 Air = 1.0 percent; cast three (35 days) (158 days) freeze-thaw beams	14,220 14,710 Air = 4.0 percent; cast three (32 days) (155 days) freeze-thaw beams	13,350 16,840 Air = 5.8 percent; cast three (31 days) (154 days) freeze-thaw beams	16,590 18,390 Air = 0.8 percent; cast three (31 days) (154 days) freeze-thaw beams	16,270 15,100 (34 days) (100 days)	5,530 8,420 Lightweight aggregate mixture; (20 days) (82 days) very harsh	7,590 7,790 Lightweight mix; worked better (19 days) (83 days) than No. 71; density 116.9 lb/ft ³	7,120 8,300 Density 121.2 1b/ft ³ (18 days) (84 days)	15,400 (102 davs)	(10,540) 12,930' Repeat of mix 22 without silica tume (17 days) (102 days)	14,140 (102 days)	11.920' Repeat of mix 35 without silica fume (102 days)
Compressive Strength, psi	14 days 28		14 , (35	16,	14,	13,	16)	16 (34	5 (20	7 (19	7 (18	14	(1) 10		
	7 days		10,400	11,600						2					
68 C. 1			8-1/2	9-1/4	8-1/2	8-1/2	6		2	10-1/2	11				
Cement/Silica	1b/yd each		0/171/66/	799/141/0	0/141/6	799/141/0	799/141/0	0/56/958	799/141/0	879/155/0	959/169/0	929/169/0	959/01169	959/169/0	959/01169
	W/C Ratio		0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.22	0.24	0.24	0.24	0.24
Mix-	No.	63	79	9	99	67	89	69	70	71	72	73	14	75	9/

Note: Strength data for mixes 73-76 are from 4 by 8 cylinders

Table 11
Mixtures with Project Limestone Coarse Aggregate

		Cement/						
		Silica Fume/	HRWR					
No.		Fly Ash,	% of	Slump,	Compress	sive Stre	ngth, psi,	at Days
Batch	W/C	1b/yd ³	Cmt Mtls	in.	6-7	14	28	90+
1	0.27	940/0/0	0.5	1/2	6,350	7350		8,820
2	0.28	940/0/0	0.5	2-3/4	5,590	7340	9,830	10,560
3	0.30	940/0/0	0.5	2	7,670	6780		
4	0.32	940/0/0	0.5	5-1/2	5,350	6440		10,630
5	0.32	940/0/0	0.5	6-1/2	4,890		6,270	6,170
7	0.30	799/141/0	0.8	6	6,300	9527	11,650	12,790
12	0.28	799/141/0	0.8	1				12,590
13	0.28	799/141/0	0.8	2	8,830		12,410	12,170
14	0.30	799/141/0	0.8	6	6,470	6960		8,030
21	0.24	799/141/0	1.0	3	11,650		14,820	15,700
22	0.24	959/169/0	1.0	7-3/4	12,110		14,640	17,080
23	0.22	959/169/0	1.0	3-1/2	12,025		13,970	17,580
28	0.24	799/141/0	1.0	3	11,255		12,800	15,630
30	0.24	799/0/141	1.0	2-1/2	9,760		11,180	13,580
32	0.24	658/141/0	1.0	7	8,470		13,510	16,200
33	0.24	658/141/141	1.0	3-1/2	9,740		14,290	16,130
37	0.24	658/141/141	1.0	6-1/2	11,050		13,390	16,130
66	0.24	799/141/0	1.25	8-1/2			14,220	14,710
69	0.24	846/94/0	1.25				16,270	15,100
73	0.24	959/169/0	1.0			14060		15,400
74	0.24	1143/0/0	1.0			10540		12,930

Table 12
Mixtures with Project Granite Coarse Aggregate

		Cement/ Silica Fume/	HRWR					
No.		Fly Ash,	% of	Slump,	Compress	ive Stre	ngth, psi	at Days
Batch	W/C	1b/yd ³	Cmt Mtls	in.	6-7	14	28	90+
24	0.24	940/0/0	1.00	8	10,195		12,490	14,290
25	0.22	940/0/0	1.00	3	11,795		11,920	14,470
26	0.24	799/141/0	1.00	3-1/2	12,490		14,680	18,780
27	0.26	799/141/0	1.00	7	10,315		14,460	17,440
29	0.24	799/0/141	1.00	3	10,110		12,990	15,810
31	0.20	902/226/0	1.00	2-3/4	10,930		14,290	17,330
34	0.24	658/141/141	1.00	3-1/2	9,650		14,000	17,470
35	0.24	959/169/0	1.00	8	10,120		16,300	16,090
36	0.26	799/141/0	1.00	7	10,910		13,010	13,745
67	0.24	799/141/0	1.25	8-1/2			13,350	16,840
68	0.24	799/141/0	1.25	9			16,590	18,390
75	0.24	959/169/0	1.00	8			-	14,140
76	0.24	1128/0/0	1.00	8				

Table 13

ELASTIC PROPERTY RESULTS

			Compressive	
	Young's	Poisson's	Strength	Split Tensile
Mixture	Modulus	Ratio	28 Days	Strength
No.	psi x 10^6	ν	psi	psi %
1101	P			
38	6.40	-	13,860	-
39	6.49	-	12,450	-
40	6.36	-	11,560	-
41	6.15	-	12,910	-
6.1	6.64	0.242	14,260	1140
64	0.04	0.242	(35 days)	(31 days)
65	6.68	0.256	16,440	1260
O.S			(35 days)	(31 days)
66	6.78	0.230	14,220	1180
00			(32 days)	(29 days)
67	5.91	0.208	13,350	1220
•			(31 days)	(28 days)
68	6.25	0.216	16,590	1440
0.5			(31 days)	(28 days)
72	3.70	0.210	7,120	
, -			(18 days)	

NES COTA 2075 Jan 75

Table 14

BOCKER BOODSTOOLS BOODS BOODS BOOKER BOODS BOOKER BOODS BOODS BOODS BOOKER BOOK

PROJECT: HIGH STRENCTH CONCRETE DATE CAST: 30 SEP 83 A	EX	EXPANSION		DATA	SHEET	<u> </u>	Lab xx Field		Page_	 • •	_ Pages	Ş
NATERIAL FOR 1-IN- N RESTRAINE No. 4 SIEVE STATE CANADA INTERIAL FOR 1-IN- N RESTRAINE No. 4 SIEVE STATE CANADA INTERIAL FOR 1-IN- PRISMS PASSED THE NO. 4 SIEVE STATE CANADA INTERIAL FOR 1-IN- PRISMS PASSED THE NO. 4 SIEVE STATE CANADA INTERIAL FOR 1-IN- PRISMS PASSED THE NO. 4 SIEVE No. 2 SIE	PRC	JECT: H	ICH STREN	CTH CONCR	ETE	-	DATE		30 SE	P 83		
NATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE AVERAGE BAR 128-0.1bs/yp3	×		1	WITHOUT	SILICA FU	3	DATE	DE MOLDED:	1 OCT 83	at 24	1	
AMTERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. 1-IN. UN RESTRAINED AGE (DAYS) 1-IN. UN RESTRAINED AGE (DAYS) 1-IN. UN RESTRAINED 1-IN. UN	Sou	urce Of	11	LABORATOR	34		Remar	ks: CONTROL I	1 1	7301 0 00	3	
1-IN. UN RESTRAINED 3-IN. UNRESTRAINED 3-IN. IN. IN. IN. IN. IN. IN. IN. IN. IN.	AST	I C 490	& ASTM C	157 PRISMS PA	SSED THE	1 1	VE.	TYPE 11	~ '	70.0 LBS/ 0.24	YD ³	
Mace (Day's) BAR % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % EXP % E		1-IN.	N D	ESTR					RESTE			
	DATE	, AGE (DAYS)	BAR	%EXP	BAR 2	% EXP	AVERAGE		% ExP		% EXP	AVERAGE
2 3 6 6 6 7 7 7 7 8 8 8 8 9	0ct 1	INITIAL	0.2643		0.2068	*****		0.1295	-	0.1161		
3 4 6 6 6 6 6 6 6 6 6 6 6 7 7 6 6 7 7 8 9 9 9 10 10 11 10 11 10 11 11 11 12 12 12 12 13 14 0.2654 0.011 0.011 0.011 0.01297 0.0027 0.1159 0.0027 0.1294 0.009 0.1171 0.010 1 0.1 0.2670 0.027 0.027 0.027 0.027 0.1304 0.009 0.1171 0.010		2										
5 4 6 6 6 6 6 7 8 9		9										
5 5 6 7 8 9 6 10 11 12 13 13 14 0.2654 0.011 0.011 0.011 0.01297 0.002 0.1161 0.000 28 0.2656 0.013 0.013 0.013 0.1294 -0.001 0.1159 -0.002 101 0.2670 0.027 0.027 0.027 0.027 0.027 0.1304 0.0304 0.1171 0.0100		•										
g 9 10 <th></th> <th>9</th> <th></th>		9										
6 9		7										
9 9 10 10 11 12 13 0.2654 21 0.011 21 0.0556 21 0.013 28 0.2656 0.027 0.013 0.027 0.1304 0.027 0.1304 0.0171 0.009		8						 				
10 10 12 13 14 15.2079 10.011 10.011 10.01297 10.002 10.1161 10.000 10.2670 10.2084 10.013 10.027		6										
12 13 0.2654 0.011 0.2079 0.011 0.011 0.01297 0.002 0.1161 0.000 21 28 0.2656 0.013 0.013 0.013 0.1294 -0.001 0.1159 -0.002 101 0.2670 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.027 0.007 0.1171 0.0100		2										
13 0.2654 0.011 0.2079 0.011 0.011 0.1297 0.002 0.1161 0.000 21 28 0.2656 0.013 0.013 0.013 0.1294 -0.001 0.1159 -0.002 101 0.2670 0.027 0.2094 0.027 0.027 0.027 0.027 0.027 0.171 0.010		=										
13 0.2654 0.011 0.2079 0.011 0.011 0.011 0.1297 0.002 0.1161 0.000 21 28 0.2656 0.013 0.2034 0.013 0.013 0.1294 -0.001 0.1159 -0.002 101 0.2670 0.027 0.207 0.027 0.027 0.027 0.027 0.1304 0.1304 0.009 0.1171 0.010		12										
101 0.2676 0.011 0.2079 0.011 0.011 0.1157 0.002 0.1151 0.010 0.1151 0.010 0		4			0.00		110	0 1307	000	0 1161	000	100 0
21 28 0.2656 0.013 0.013 0.013 0.013 0.01294 -0.001 0.1159 -0.002 1 101 0.2670 0.027 0.027 0.027 0.1304 0.009 0.1171 0.010	- 1	_	0.2654	0.011	0.20/9	0.011	0.011	0.129/	0.002	0.1101	000.0	
28 0.2656 0.013 0.2084 0.013 0.027 0.027 0.027 0.027 0.027 0.1304 0.009 0.1171 0.010		_			300			0 130	100	0 1150	-0.002	-0.002
101 0.20.0 0.02.1	Oct 28	1	0.2656	0.013	0.2081	0.013	0.013	0 1304	000	0 1171	010	010
	Jan 10	4	0.7970	0.02/	0.2094	0.02/	0.027	0:1304	0:00	7:177	7.010	0.010

WES LOTH 2076 Jan 75

Table 15

PROJECT: HIGH STRENGTH CONCRETE MIX DESIGN: NO. 22 WITH SILICA FUNE SOURCE Of Data: LABORATORY ASTM C 490 & ASTM C 157 MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. DATE AGE (DAYS) 8AR ! % EXP 8AR 2 % EXP AVE OCT 1 INNTIAL 0.2574 0.2408 2 3 4 5 6 7 7 10 10	DATA SHEET Lab_xx Field Pageof Pages
DUTCE OF DOTO: LABORATORY STM C 490 & ASTM C 157 ATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. AGE (DAYS) BAR 1 % EXP BAR 2 % EXP INITIAL 0.2574 0.2408 3 4 5 6 7 8 9 10 11	TH CONCRETE DATE CAST: 30 SEP 83
ATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. ALERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. AGE (DAYS) 8AR 1 % EXP 8AR 2 % EXP NITIAL 0.2574 0.2408 2 2 3 4 4 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	WITH SILICA FUME DATE DEMOLDED: 1 OCT 83 of 24 HRS Age
ATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE. 1-III. UNRESTRAINED AGE (DAYS) 8AR 1 % EXP 8AR 2 % EXP INITIAL 0.2574 0.2408 5 5 6 7 7 10 11	Remarks: TEST MIXTURE
1-14, UNRESTRAINED AGE (DAYS), BAR i % EXP BAR 2 % EXP INITIAL 0.2574 0.2408 5 6 7 8 9 10	TYP SILLS
1-III, UNRESTRAINED AGE(DAYS), BAR i % EXP INITIAL 0.2574 0.2408 3 4 5 6 7 8 9 10	# SIEVE: WATER 2/0.1
AGE (DAYS) BAR i % EXP BAR 2 % EXP INITIAL 0.2574 0.2408 3 4 5 6 7 7 8 9 10	TRAINE
INITAL 0.2574 0.2408 3	BAR 2
2	0.2408
6 4 6 6 7 1 1 1 0 6 6 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1	
4 % % 4 % 7 % 4 % 7 % 4 % 4 % 4 % 4 % 4	
9 6 7 7 6 6 7 1 1 1 1 1 2 1	
8 8 9 10 11 11	
9 9 1 1 1 1 1 1 1 2	
9 6 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
10 10 11 11	
10 11 11	
12	
000 0	200 0 200 0 200 0 200 0
21 0.25/4 0.000 0.2408 0.000	0.2408
28 0.2573 -0.001 0.2407 -0.001	0.2407 -0.001 -0.001 0.1293 -0.011 0.1311 -0.012
Jan 10 101 0.2580 0.006 0.2414 0.006 0.0	0.2414 0.006 0.006 0.1301

WES Form 1976

Table 16

û	EXPANSION	N O	DATA	SHEET	1	Lab_xx_ Field	ield	Page_	of	_ Pages	S
PR(PROJECT: HIGH STRENGTH CONCRETE	HIGH STRE	NCTH CONC	RETE		DATE	CAST:	30 83	30 SEP 83		
×	C DESIGN:_	NO.	35 WITAOUT SILICA FUME	SILICA	UME	DATE	DEMOLDED: 1 oct 83	. 1 OCT 8	3 at 24 HRS	HRS Age	•
So	Source Of		LABORATORY	X		Remarks:	1 1	MIXTURE		-	
MAZ	ASTM C 490 & ASTM MATERIAL FOR 1-IN	~ I • I I	C 157 PRISMS PASSED THE NO.	ED THE NO	. 4 SIEVE.		MATER WACER	CEMENT	128.0 LBS/YD ³ 270.7 LBS/YD ³ 0.24	D ₃	
	J-IM.	ח	RESTRAINE		۵۱	-	ZIM UN	UNRESTRAINE	RAINE	۵	
DATE	AGE (DAYS)	BAR -	%EXP	BAR 2	% Exp	AVERAGE	BAR	% ExP	BAR 2	% EXP	AVERAGE
0ct 1	INITIAL	0.1420		0.1253		1	0.1381		0.1344	1	1
	2										
	2										
	•										}
	٥										
	7										
	8										
	6										
	2							 - -			
	=										
	12										
	-13					:					
Oct 14	4	0.1431	0.011	0.1263	0.010	0.011	0.1380	-0.001	0.1344	0.000	-0.001
	21										
Oct 28	28	0.1431	0.011	0.1266	0.013	0.012	0.1377	-0.004	0.1341	-0,003	-0.004
Jan 10	101	0.1444	0.024	0.1279	0.026	0.025	0.1389	0.008	0.1352	800.0	0.008

<u>Possovalendavani somnosieropani iropopori iropopateli kanarasi irosakani iropopopori iropopopori iropopo</u>

EES Corm 2076 Jan 75

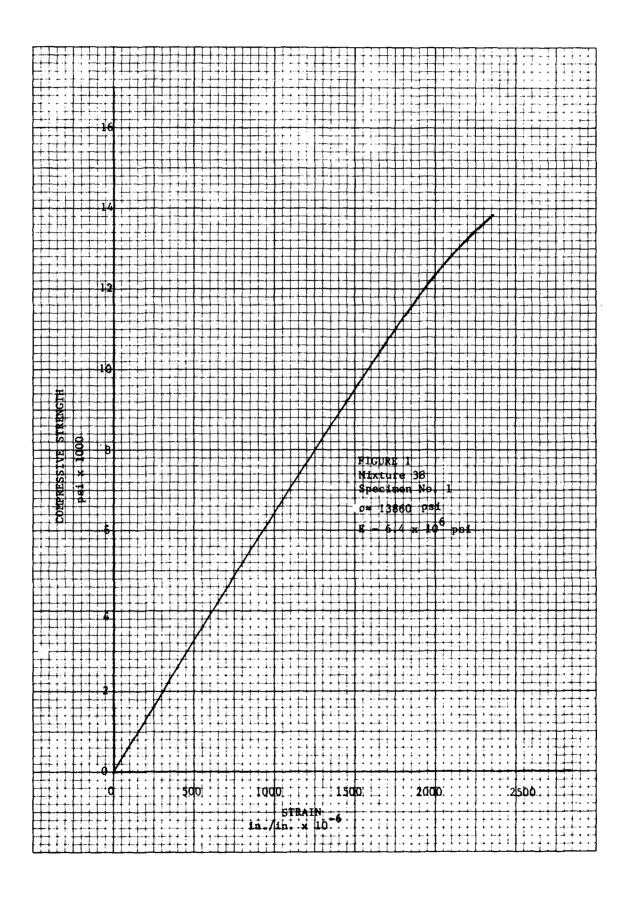
Table 17

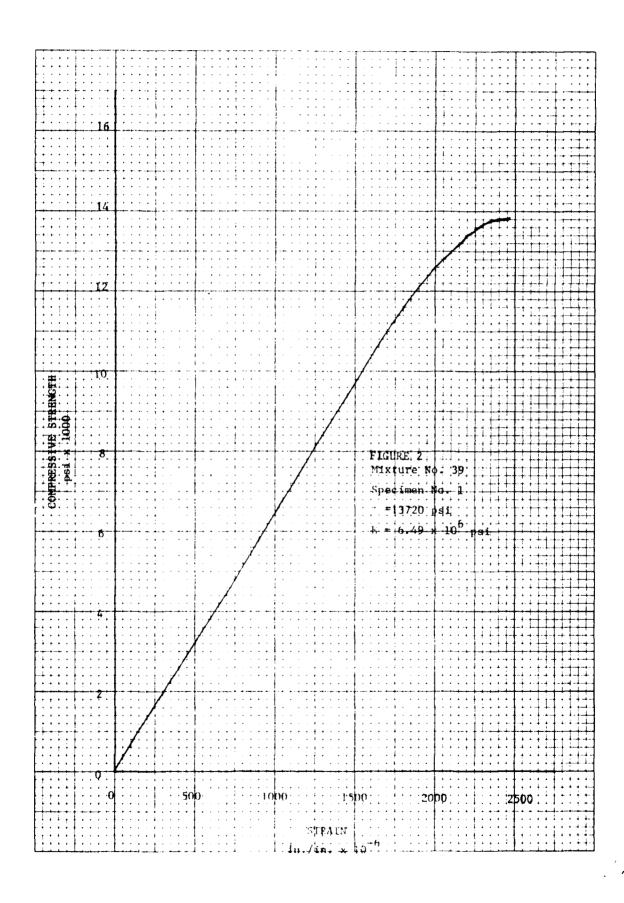
EX	EXPANSION	ON	DATA	DATA SHEET	ΕT	Lab_xx_ Field	ield	Page_	_ of _	_ Pages	Se
PRO	JECT:	HIGH STR	PROJECT: HIGH STRENGTH CONCRETE	CRETE		DATE	DATE CAST:	30 SE	30 SEP 83		
×	MIX DESIGN: NO.		35 WITH SILICA FUME	LICA FUME		DATE	DE MOLDED: 1 OCT 83	1 OCT 8	3 at 24 HRS	HRS Age	80
Sou	Source Of	Of Data:	LABORATORY	KY.		Remarks:	ks: TEST MIXTURE	TURE			
AST	ASTM C 490 & ASTM C		157				TYPE II CEMENT		958.8 LBS/YD3	D ₃	
MAT	MATERIAL FOR 1-IN	٠,١	RISMS PAS	PRISMS PASSED THE NO.	. 4 SIEVE		SILICA FUME WATER W/C		169.2 LBS/YD3 270.0 LBS/YD	D3	
	1-IN	1-IN, UTI R	RESTR	RAINE	۵۱		3-IN NRESTRAINE	RESTE	AINE	٥	
DATE	AGE (DAYS) BAR	BAR	% EXP	BAR 2	% EXP	AVERAGE	BAR	% EXP	BAR 2	% EXP	AVERAGE
0ct 1	INITIAL	0.2658		0.3052			0.1318		0.1300		
	2										
	3										
	4										
	\$										
	9										
	7										
	8 0 6										
	01										}
	11										
	12										
	13										
Oct 14	4	0.2658	0.000	0.3049	-0.003	-0.002	0.1312	-0.006	0.1293	-0.007	-0.007
	21										
Oct 28	28	0.2657	-0.001	0.3047	-0.005	-0.003	0.1309	-0.009	0.1290	-0.010	-0.010
Jan 10	101	0.2664	900.0	0.3055	0.003	0.005	0.1316	-0.002	0.1297	-0.003	-0.003

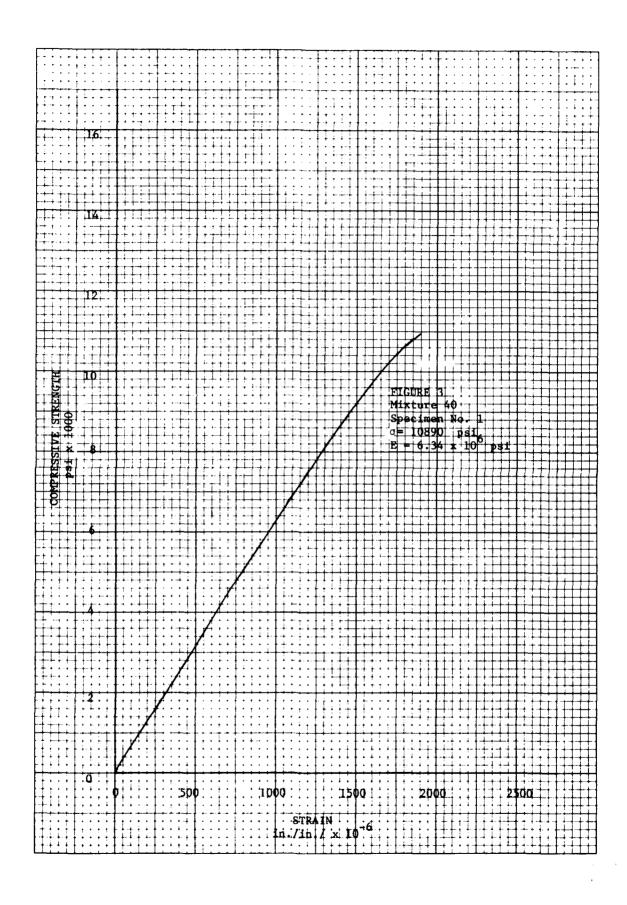
			(CRD-C	13, 25,	40, 47,	114, 38, 3	6,37, 35,	,124)					
MBOL:		JOB N	o: 441-S			EMO NO:				TE: 8-	-5-83	11	IITIALS:	DMW
IOJECT:	HIGH STR				SI	PECIMEN	TYPE: 3-1	/2 X					FI	LAR B
	D: 8/8/83	DATE	CORED:		Cl	JRING: T	PE: Inun	date	l Fot	Room	1			28 D
NE AGG:	Limesto	ne OM	19 S-	1	CC	DARSE AG				19 G-			MAX.	1
	C (894(1		F. B/CY.				ACT. C.	F. B/CY:	940	cmt+s	ilfu	me S/A	\$ VOL:	40
	<u> 4.0</u>	JN-11	1/2:			W/C		24			P IN. (-1	1/2):	8-1/	2
1. U.W. LB					ACT. U.	W. (PLAST	IC):			ADMIX	!: 			
	FAT BEAMS C114 C C13 C		ORES SPEC. C 35, 1		HWCD C 40		DCW 40 D	SHRIN C 25		HEAT RIS		FFUSIV.		ER ()
EGIN		<u> </u>	- 1000,.		340 5			+				30,7 0	- 322	N CHING
ATE:	97-91				ļ									
PEC. NO.	87-84					1								
	<u> </u>					FOT D	ESULTS							
A) (B) 00 100 _[ESI R	50							
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70 40		ŀ					RISE,		<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	
70 40 						+	20 - E	SPEC.	HEAT	RISE, F	DIFF,	SPEC.	RFM	ARKS
- 1		ļ	ļ			1	P	NO.	70	14 D	FT 2/HR	HEAT		
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				J.			}。	-	 	├ ──			├ ──	
- 0	50	100 NO. OF CYCL	150 ES (A) (B): 1	200		250	0 300							
0		NO. OF CYCL	150 LES (A) (B): 1			250		DENSITY		ED) LB/C	U. FT ⁻			
0 (A) FOR 3	1/2×41/2×16	NO. OF CYCL				250		DENSITY		ED) LB/C	U. FT·			
A) FOR 3 B) FOR CO		NO. OF CYCL IN BEAMS	.ES (A) (B): 1	TIME HE	R (C)		300		INITIA	.s:				
(A) FOR 3 (B) FOR CC (C) FOR TE	1/2×41/2×16 DRE SPECIMENS	NO. OF CYCL IN BEAMS	ES (A) (B): 1	MIX	R (C)	. 66	300	MIXT	NO NO	.s:				
(A) FOR 3	1/2×41/2×16 DRE SPECIMENS	NO. OF CYCL IN BEAMS	ES (A) (B): 1	MIX	R (C)	. 66	300	MIXT	NO NO	.s:			DATE TE	
A) FOR 3 B) FOR CC C) FOR TE	1/2 X 4 1/2 X 16 DRE SPECIMENS EMPERATURE RIS	NO. OF CYCLIN BEAMS SE LAB	TRIAL	MIX	T NO	. 66 NO. O F	(TEST	MIXT:	NO VN	CONT	ROL)		DATE TE	
A) FOR 3 B) FOR CC C) FOR TE	1/2 X 4 1/2 X 16- DRE SPECIMENS EMPERATURE RIS	NO. OF CYCLIN BEAMS SE LAB	TRIAL RELA	MIX TIVE	T NO E AT	. 66 NO. OF	(TEST CYCLES 256	MIXT:	INITIAL NO	CONT	ROL)			
A) FOR 3 B) FOR CC C) FOR TE SPEC. NO. Cycles 9781	1/2 X 4 1/2 X 16- DRE SPECIMENS EMPERATURE RIS 0 100	NO. OF CYCLE IN BEAMS SE LAB 47 96	TRIAL RELA 93 95	MIX TIVE 15	T NO E AT	. 66 NO . OF 210 95	(TEST CYCLES 256 93	MIXT:	NO VN	CONT 356	ROL)			TED:
A) FOR 3 B) FOR CC C) FOR TE SPEC. NO. Cycles 9781	1/2 X 4 1/2 X 16 ORE SPECIMENS MPERATURE RIS 0 100 100	NO. OF CYCLIN BEAMS SE LAB 47 96 96	TRIAL RELA 93 95 96	MIX TIVE 15 9	E AT 1666	. 66 NO. OF 210 95 95	(TEST	MIXT:	NO NO 294 86 77	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE PEC. NO. V. C. Les 781	1/2 X 4 1/2 X 16- DRE SPECIMENS EMPERATURE RIS 0 100	NO. OF CYCLE IN BEAMS SE LAB 47 96	TRIAL RELA 93 95	MIX TIVE 15 9	T NO E AT	. 66 NO . OF 210 95	(TEST CYCLES 256 93	MIXT:	NO VN	CONT 356	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE PEC. NO. V. C. Les 781	1/2 X 4 1/2 X 16 ORE SPECIMENS MPERATURE RIS 0 100 100	NO. OF CYCLIN BEAMS SE LAB 47 96 96	TRIAL RELA 93 95 96 96	MIX TIVE 15 9	E AT 162 16 17	. 66 NO. OF 210 95 95 95	(TEST	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE PEC. NO. V. C. Les 781	1/2 x 4 1/2 x 16 ORE SPECIMENS EMPERATURE RIS 0 100 100 100	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 95 94	(TEST CYCLES 256 93 91	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE PEC. NO. V. C. Les 781	1/2 X 4 1/2 X 16 ORE SPECIMENS MPERATURE RIS 0 100 100	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 95 94	(TEST CYCLES 256 93 91	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE EPEC. NO. 2. C. Les 2. 781	1/2×41/2×16 ORE SPECIMENS EMPERATURE RIS 0 100 100 100 Relativ	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 95 94	(TEST CYCLES 256 93 91	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE EPEC. NO. 2. C. Les 2. 781	1/2 x 4 1/2 x 16 ORE SPECIMENS EMPERATURE RIS 0 100 100 100	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 95 94	256 93 93 91	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE SPEC. NO. Cycles 9781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 210 95 95 94 MINAT	(TEST) (CYCLES) 256 93 93 91 ON AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE SPEC. NO. Cycles 9781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 210 95 95 94 MINAT	(TEST) (CYCLES) 256 93 93 91 10N AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE EPEC. NO. 2. C. Les 2. 781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781 9782	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO 180 180 64 43	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
on for 3 b) for cc pfor te pec. No. Yeles 781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE PEC. NO. V. C. Les 781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781 9782	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO 180 180 64 43	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE SPEC. NO. Cycles 9781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781 9782	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO 180 180 64 43	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE EPEC. NO. 2. C. Les 2. 781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781 9782	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO 180 180 64 43	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT: SHOV	NO VN 294 86 77 93	S:	ROL)		COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE SPEC. NO. Cycles 9781	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781 9782	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO 180 180 64 43	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT:	NO VN 294 86 77 93	S:	ROL)	IALS:	COMPLE	TED:
A) FOR 3 B) FOR CC C) FOR TE	1/2×41/2×16 DRE SPECIMENS IMPERATURE RIS 0 100 100 100 Relativ Cycles 9781 9782	NO. OF CYCLIN BEAMS SE LAB 47 96 96 97	TRIAL RELA 93 95 96 96 REPO 180 180 64 43	MIX TIVE 15 9 9 ORT C	T NO E AT	. 66 NO. OF 210 95 95 94 MINAT	93 93 91 10N AFTI	MIXT: SHOV	NO VN 294 86 77 93	S:	ROL)	IALS:	COMPLE	TED:
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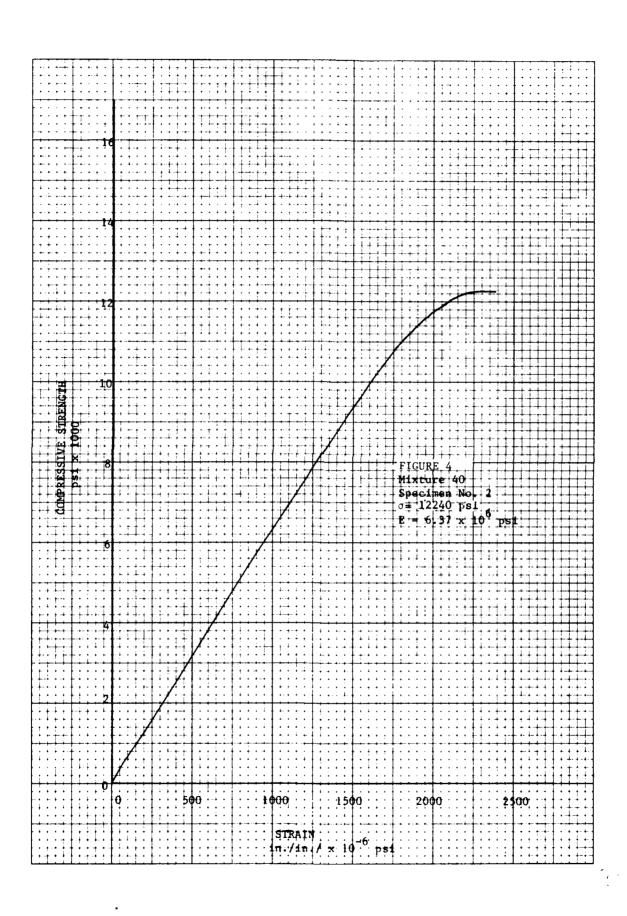
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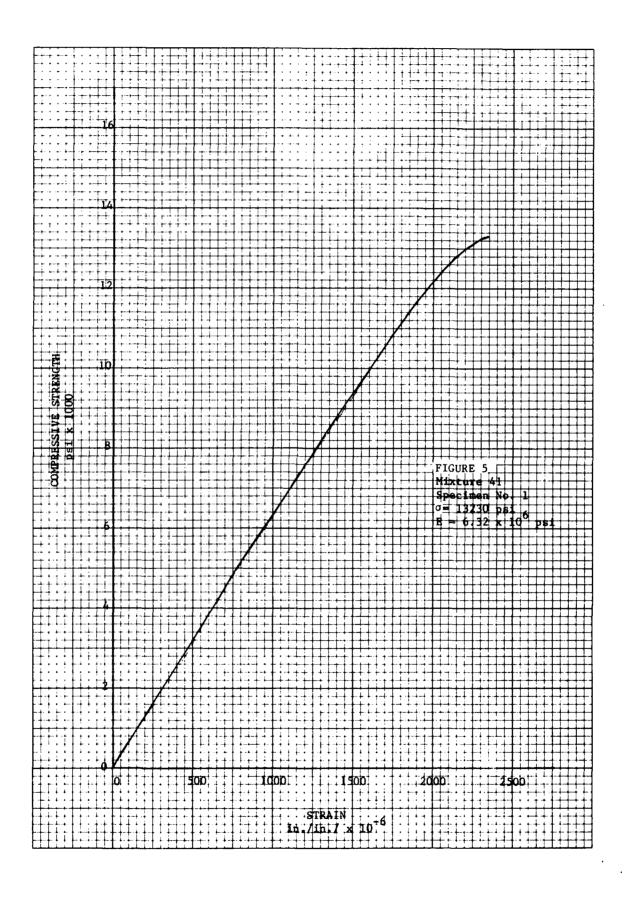
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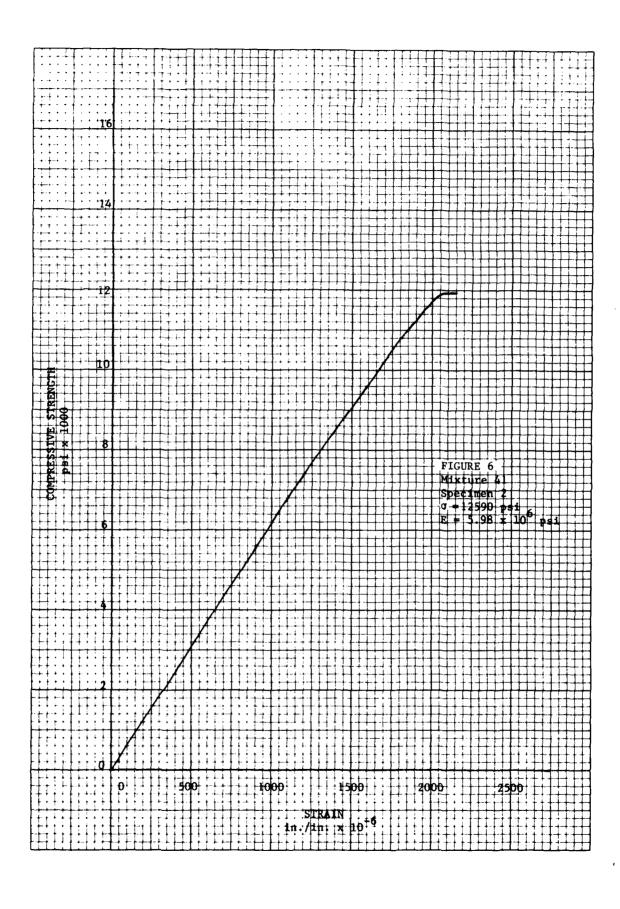


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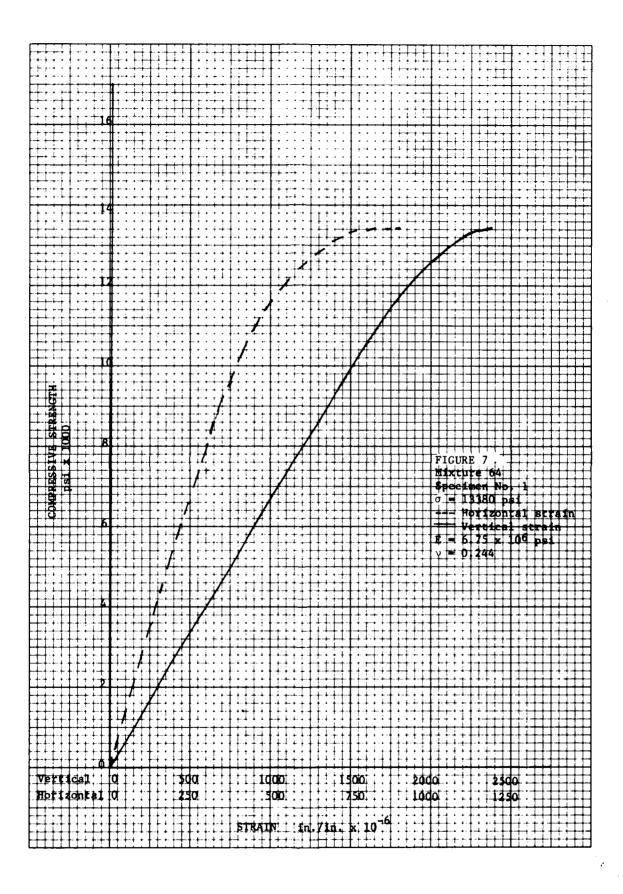




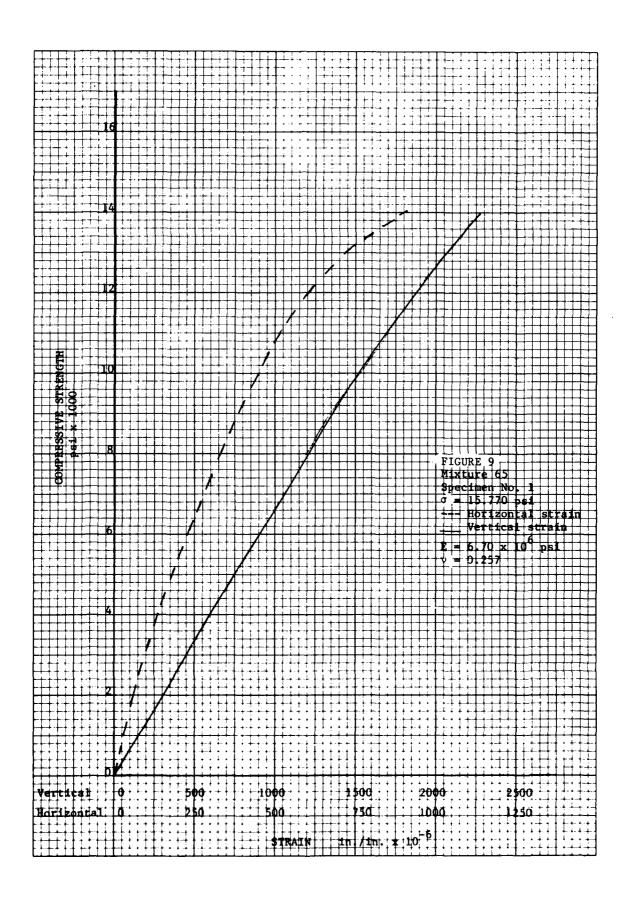


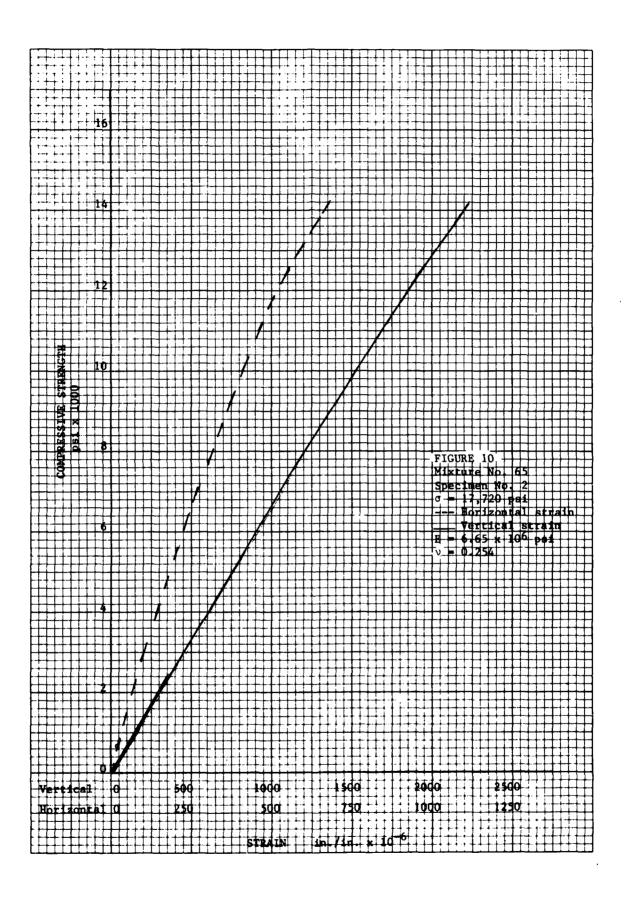


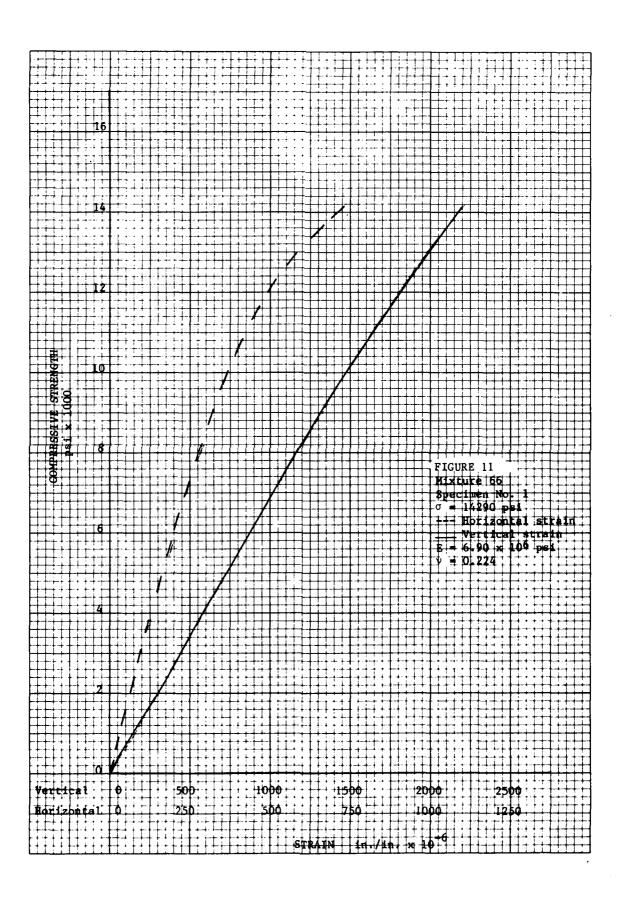
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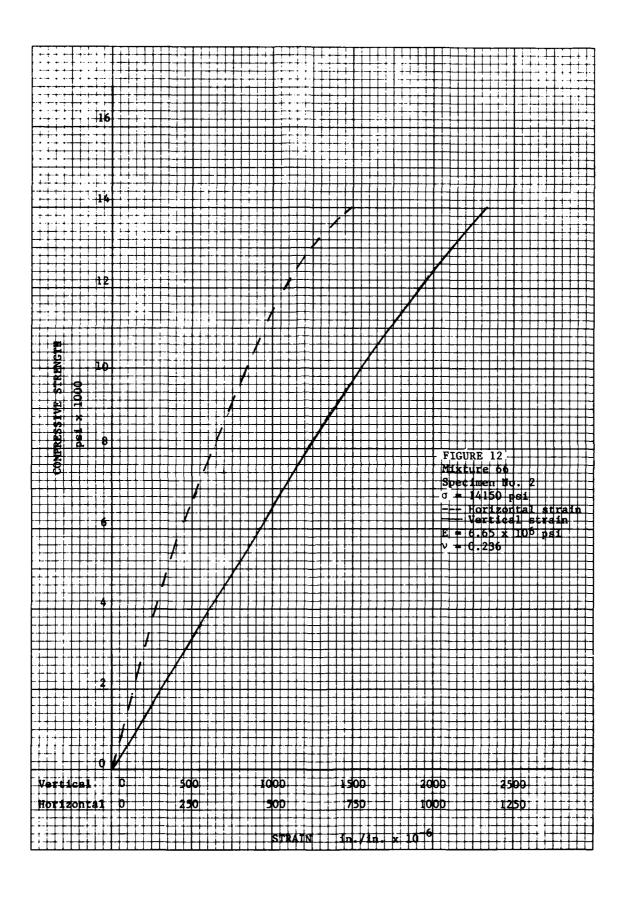


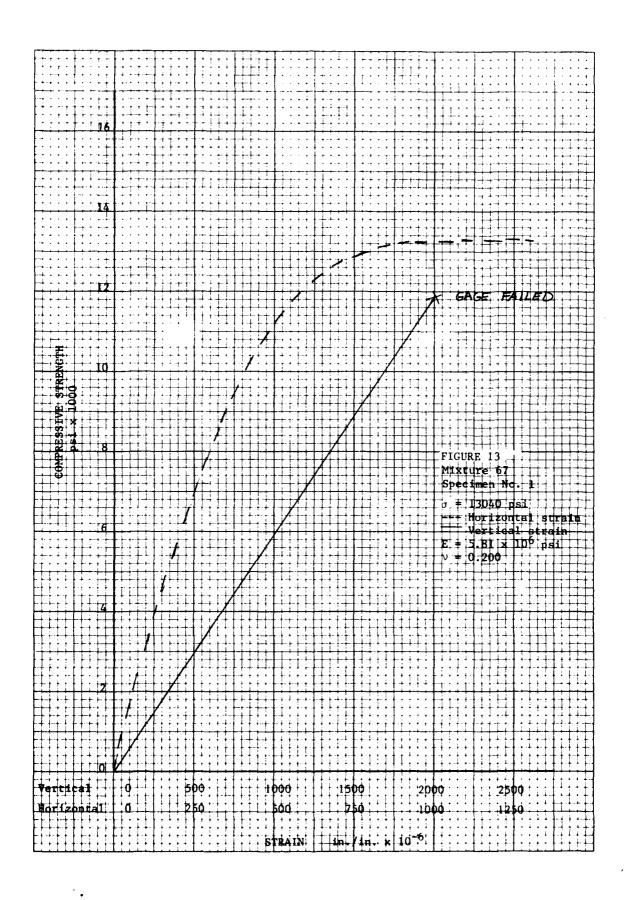
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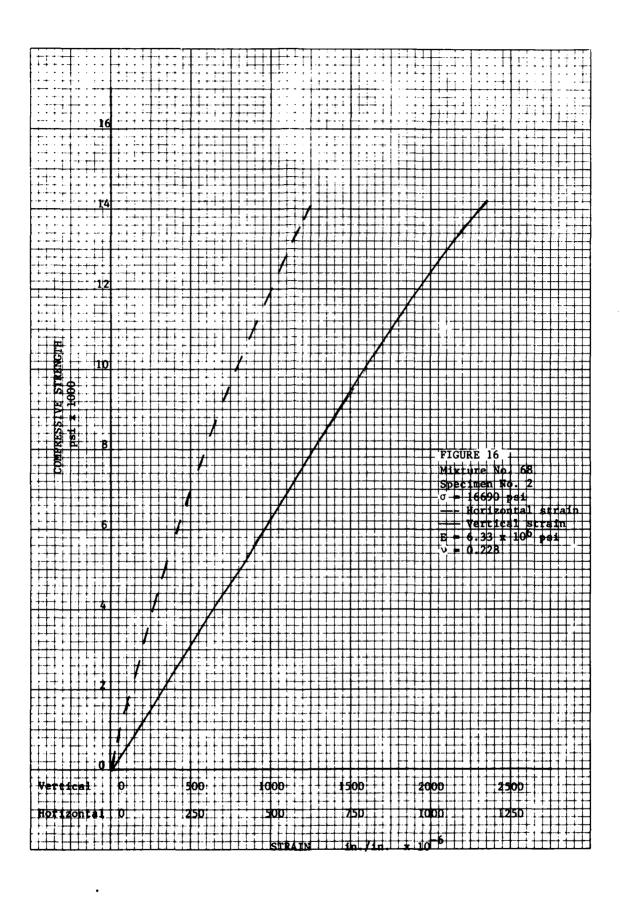








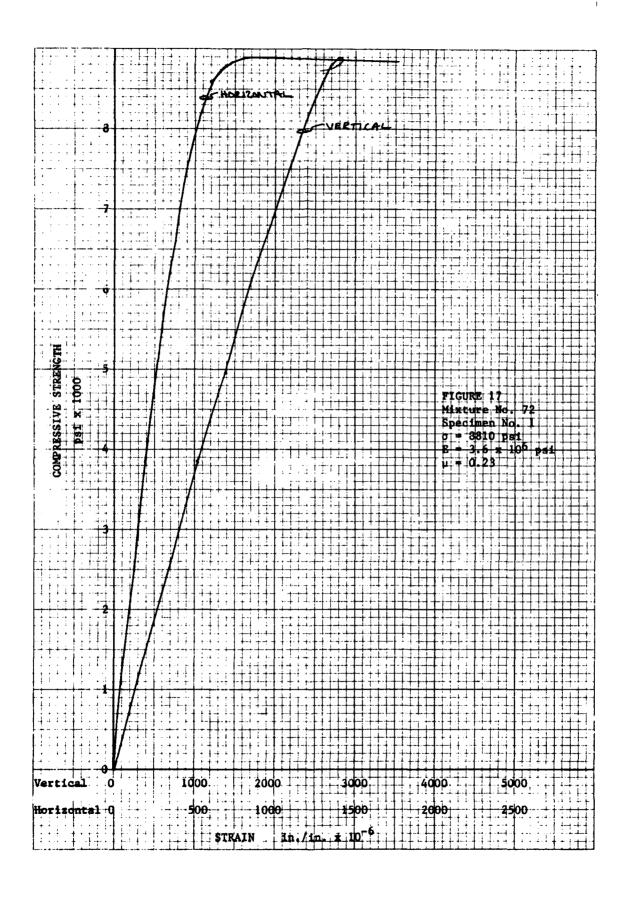
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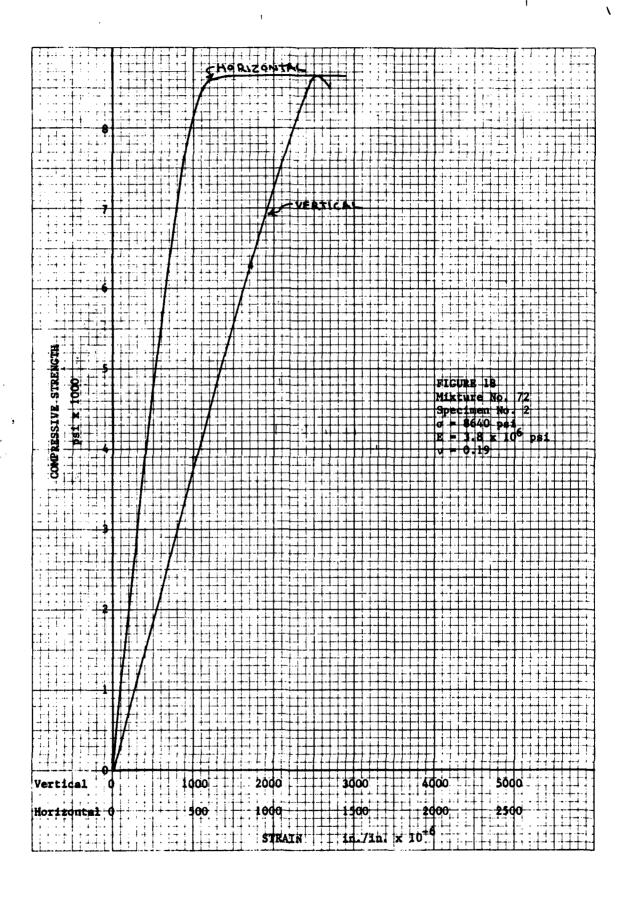


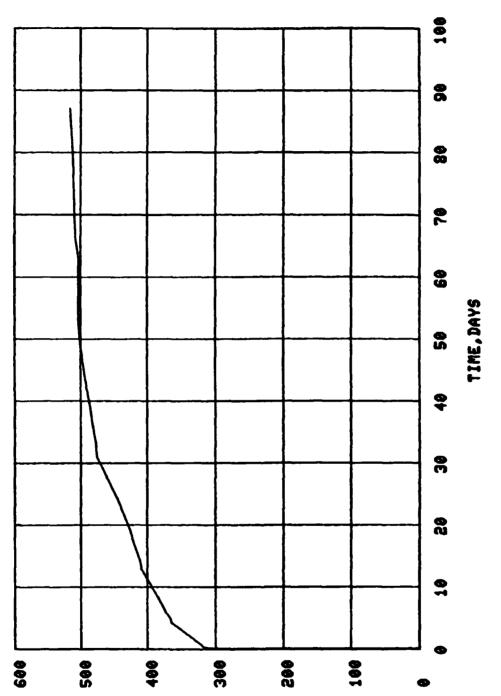
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Figure 19. Total strain during loading period for mixture 22 with silica fume

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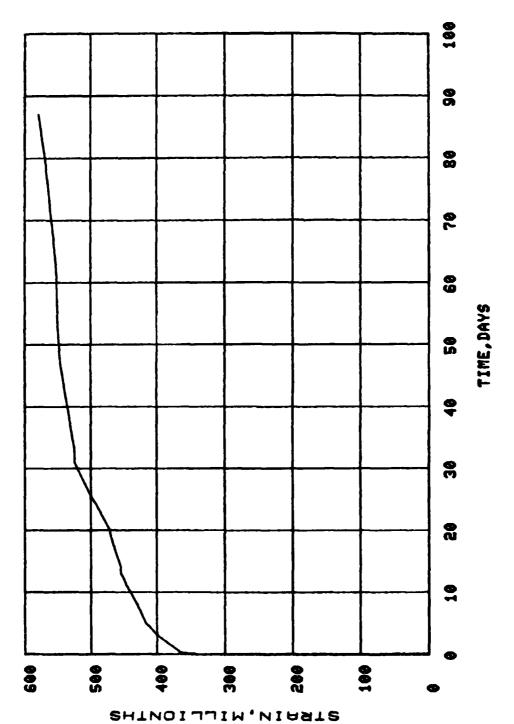
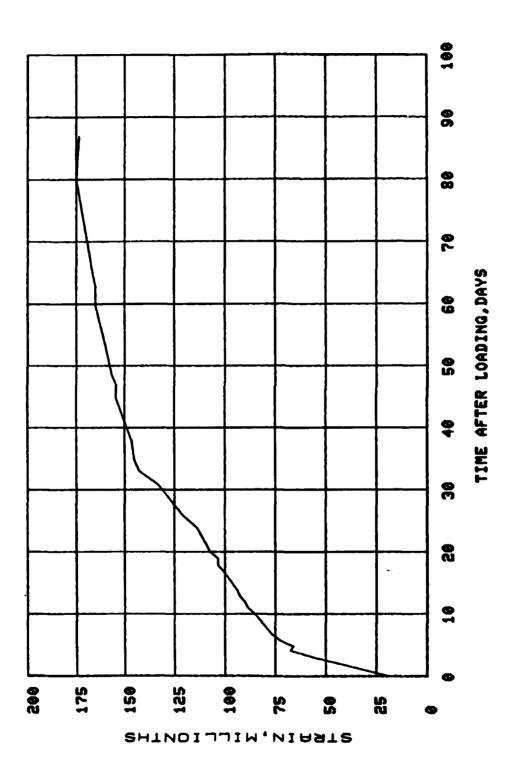
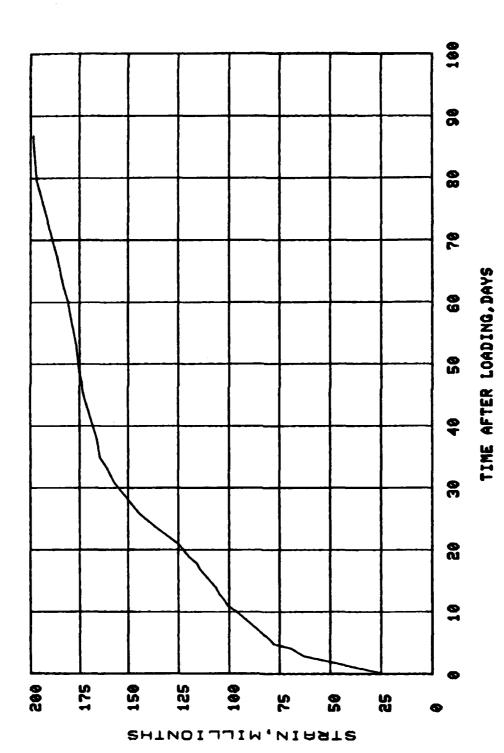


Figure 20. Total strain during loading period for mixture 22 without silica fume



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Corrected creep strain for mixture 22 with silica fume; loaded to 2000 psi at 14-day age (unconfined) Figure 21.



Corrected creep strain for mixture 22 without silica fume; loaded to 2000 psi at 14-day age (unconfined) Figure 22.

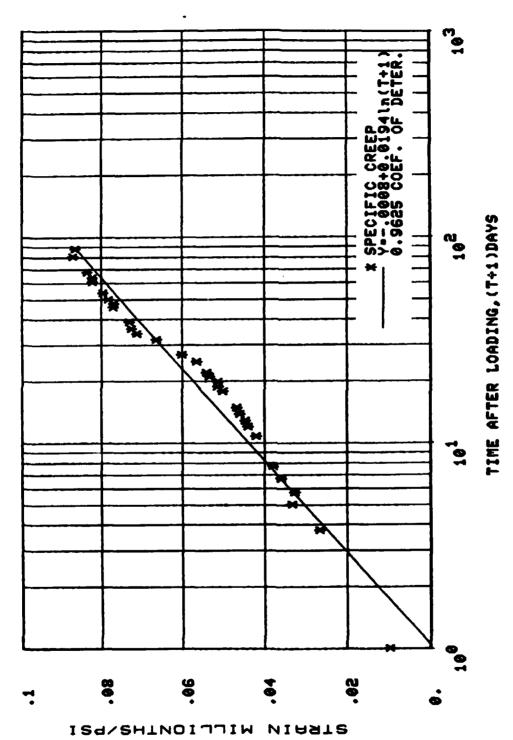


Figure 23. Specific creep for mixture 22 with silica fume; 1oaded to 2000 psi at 14-day age (unconfined)

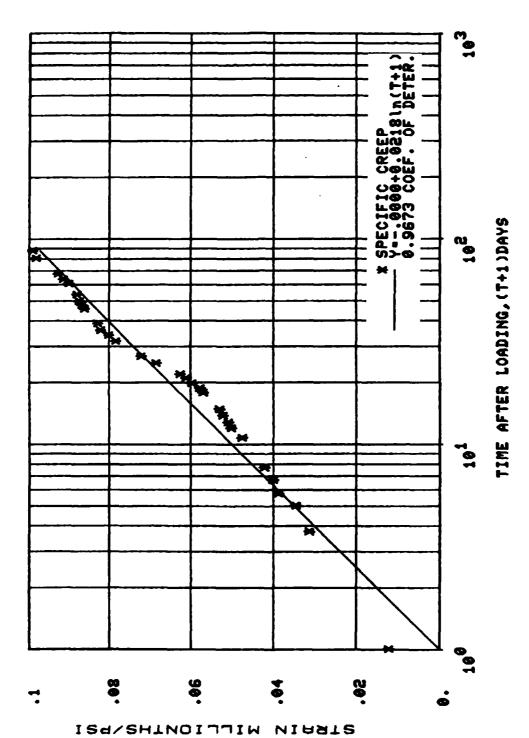


Figure 24. Specific creep for mixture 22 without silica fume; loaded to 2000 psi at 14-day age (unconfined)

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